UNIVERSITY OF LIVERPOOL

Deliberation and implementation activity in forced-choice decision making environments:

Variations in information processing within a neurocognitive framework

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor of Philosophy

By

Michael H. D. Humann

September, 2011

ABSTRACT

This thesis examined decision making in the context of forced-choice situations, as characterised by high-risk consequences and time-limited conditions, within an experimental decision paradigm. By mapping onto basic decision-making stages relating to evaluation, deliberation and implementation of a choice, this research looks at how environmental conditions (emotion) and information (advice) affect cognitive processing in forced-choice or "do or don't" scenarios. In order to identify these variations on a more fundamental level, a methodological framework was developed, which incorporates neurocognitive, behavioural and qualitative measures.

Results identified the distinct sequence of cognitive processes as predicted from basic decision-making models. When individuals lacked any meaningful information to assist in solving the tasks, their responses varied based on the consequential conditions they faced, leading to an accelerated engagement with the decision and faster response, the riskier the outcome. On the other hand, when information was available during the task, differences in responses followed predictions about information processing and cognitive effort required for the different levels of clarity. Here, the consequential conditions did not affect performance, as individuals prioritised the information available. Further, when solving a task lacking any meaningful information on which to base their choice, individuals still engaged in redundant deliberation. Taken together, the research suggests that outcome uncertainty and task ambiguity have a demonstrable effect on the decision-making process.

This research, incorporating neurocognitive measures, showed a robust framework to advance current understanding about the interplay of affecting factors and basic decision-making processes. Providing an additional reference, this approach contributes to a more in-depth picture of underlying processes.

ACKNOWLEDGEMENTS

A number of people have contributed to the completion of this thesis, and a few of those merit special thanks for their support and significant contribution.

Professor Laurence Alison, for whom I am immensely grateful to for his support, advice and patience. He was always able to encourage ideas and conversations, allowing me to articulate new propositions, enthusiastic about the possibility of advancing work in more unfamiliar areas.

Professor Andrej Stancak, whose guidance was invaluable in the development of my ideas, and whose support helped me to advance these into new territories.

Everyone at the University of Liverpool, and especially those people in the Centre for Critical and Major Incident Psychology, for their help and friendship. I would like to thank all those who assisted me during the data collection, and further supported me throughout my time in Liverpool.

My good friends, near and far, who have helped me more than they will ever know.

My family, for being supportive and enabling me to pursue new challenges, and encouraging me always to follow the goals that I set-out for myself.

Finally, to all the professionals and participants who took time to take part in this research.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter I

Introduction

From thinking about acting, to doing so

One of the most-challenging characteristics of decision making in so-called critical incidents is that it often requires choosing between to equally unattractive options. This is done in environments of high ambiguity about the information available, while at the same time dealing with uncertain outcomes. Individuals in these settings are faced with high performance expectations, operational pressures, limited time available and mostly dealing with highly consequential situations, due to the high-risk nature of the problems. This translates to the potential for negative outcomes and a heightened emotional state. The main goal of this thesis is to identify – through the application of techniques and methodologies from the fields of social psychology and neuroscience – the individual cognitive processes during key stages of decision making, and how these are affected by factors relating to situational settings and information available.

The main aim of this research is to further advance the knowledge from the emerging fields of **social neuroscience** and **neuroeconomics**, to include specific operational conditions identified within naturalistic and real-life decision making environments. By reference to the *cognitive substrates* and *behavioural correlates* of decision making, the goal is to understand how individuals process task demands and information. In particular we are interested in experimental settings characterised by naturalistic high stake situations.

While simple decision-making environments allow for clear constraints and the assignation of values for the available alternatives, more challenging ones demand high operational competency from individuals under *extreme conditions*. This translates into additional task pressures and factors influencing the whole decision-making process. Leading on from a **naturalistic decision making (NDM)** perspective, the challenge here has focused on identifying key factors, which characterise *unstructured problems*, and incorporate those in basic decision-making tasks. The aim has been to develop experimental paradigms which mirror fundamental pressures of particular environments, in order to isolate individual decision-making processes, with a view to identifying the stages of evaluation, deliberation and implementation of choices.

Our focus here is on forced-choice environments, as encountered in situations of high risk and uncertainty. The prime challenge during critical incidents lies in the need to choose between two equally (un)attractive options, under conditions of high time pressure and significant risk. The goal is to combine *neurocognitive, behavioural* and *qualitative* measures, to further identify the particular decision making processes that individuals engage in when solving tasks under those conditions. This insight will contribute to the fundamental understanding of the interplay between performance pressures and information, and how these affect individuals' response.

1.1 Problem of Choice

The most fundamental action any individual performs has a key preceding condition: the decision to perform said action. Sometimes individuals operate within environments where the need to make a choice is not so much voluntary or optional, but prescribed by the operational conditions and the particular pressures of the situation – these are what we regard as "*do or don't*" moments. These decisions are often characterised by limitations in terms of the available courses of actions an individual can consider, with limited or no information available on which to base decisions.

Furthermore, these environments are often characterised by time constrains, and involve a high degree of risk and negative consequence as potential outcomes. These can include pilots in emergency situations, missile operators needing to reassess launch settings, or operators faced with an unexpected system shut-down. It is not only the sheer complexity of these environments, but the notion that individual steps are needed to gain clarity and an overview of the situation. It is these forced-choice decision-making environments that are of interest here, as the aim is to describe if, and how, individuals' decision making is affected by these particular operational settings. The goal is to trace the neurocognitive processing during the decision-making process, with particular emphasis on the final commitment to a choice, which requires both deliberation (evaluation of alternatives) and implementation (commitment to a course of action).

1.2 Decision Making

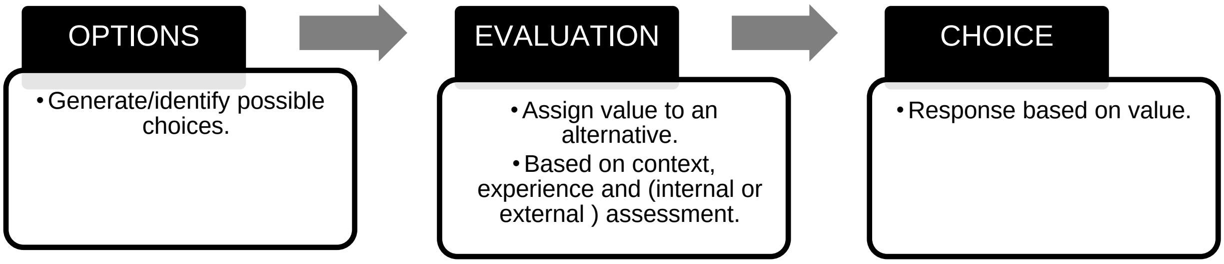
Decision making has been defined as "*the process commonly portrayed as occurring early in the 'problem-solving process' - the sensing, exploration, and definition of problems or opportunities - as well as the generation, evaluation, and selection of solutions*" (Huber & McDaniel, 1986; p.576). All of these dynamic and interrelated processes have been observed and analysed from a number of research perspectives, and the challenge has focused on establishing a valid narrative, describing reasoning and behaviour applicable to each setting. Research has approached the task from two distinct starting points, with varying degrees of concordance (Kahnemann & Klein, 2009), but an understanding of both is key here, in order to advance the current proposals.

TDM

Based on traditional decision-making (TDM) theory, the focus will be on a simplified model, breaking decisions down into three interrelated processes: options, evaluation, and choice (Herrnstein & Prelec, 1991; Baron, 1994; Lipshitz, Klein, Orasanu, & Salas, 2001). In particular, we will follow on from the decision-making stages proposed by Gollwitzer, Heckhausen, and Steller (1990), which describe in more detail individuals' evaluation, deliberation and implementation of decisions within a TDM framework.

It is important to bear in mind that while the distinction of these three stages of decision making is to some extent arbitrary, it still provides a starting point for a more systematic examination of the individual component processes.

Figure 1. 3-Stage Decision Making Model (adapted from Fellows, 2004)



It is within this model that we consider the generation of possible options, the evaluation process applied to all of these available options, and the final commitment to one specific one.

Options

The generation and recognition of options has been investigated by a number of researchers (Baron, 1994; Russo & Schoemaker, 1990; Gigerenzer & Todd, 1999), but the effect of forced-choice environments has received little attention. These particular settings lack the options-generation component, but raise other questions about the lack of influence and effect the decision-maker has over the task or problem. These are environments of *do-or-don't* moments, from the simple level of deciding whether or not to make a purchase, or the more high-risk levels in law-enforcement, deciding whether or not to shoot a suspect. These lack the option-generation stage, but still follow a similar dynamic on the most fundamental level. So it is worth looking at the subsequent stages, and see how these play out in forced-choice environments.

Evaluation

Evaluation has been examined principally from an economic framework, as the subjective utility an individual places on the particular courses of action (Keeney

& Raiffa, 1976; Glimcher & Rustichini, 2004) and from a reward perspective, seen as an intrinsic stimulus property (Baxter & Murray, 2002), fulfilling primary needs (Richardson & DeLong, 1991), as well as dependence needs (Breiter & Rosen, 1999), with some mixed results for studies using specific rewards (Knutson, Adams, Fong, & Hommer, 2001; Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001; Pochon, Levy, Fossati, Lehericy, Poline, Pillon, Le Bihan, & Dubois, 2002).

In these environments, the focus is on uncertain problems, with no clear value stated for each of the (prescribed) options and with limited feedback. This makes it almost impossible for the individual to develop or learn a pattern of value, thus reinforcing the difficulty and complexity of the task. As a result of the characteristics of these environments, it is impossible to develop a meaningful assessment of the alternatives, or assign to them a *neural currency* (Montague & Berns, 2002). Decision makers have no information on which to generate value or judgement about individual alternatives, from which to develop a meaningful preference.

Further, research has shown that beliefs about outcomes are vital to the evaluation process, particularly when assessing the various attributes of choice alternatives (Shanteau, 1980), as well as during the active search for information relevant to the decisions (Böckenholt, Albert, Aschenbrenner, & Schmalhofer, 1991). Barlas (2003) proposed that the importance with which one perceives a decision is crucial, because such perceptions are instrumental in evaluating tradeoffs between conflicting attributes of choice. It is this added dimension which influences levels of cognitive processing invested in decision formulation. These environments include varying levels of outcome, which directly influence the evaluation process at different stages, providing another factor affecting the overall decision-making process.

Choice

Despite the difficulties and complexities present in the first two stages of the decision-making model, decision makers are still under pressure and are required to make a choice and commit to a particular course of action. Recent research has looked into some issues relating to response selection, based mostly on an individual's previous evaluation of the decision context (Bush, Vogt, Holmes, Dale, Greve, Jenike, & Rosen, 2002; Gehring & Willoughby, 2002; Knutson, Fong, Bennett, Adams, & Hommer, 2003; O'Doherty, Critchley, Deichmann, & Dolan, 2003), while research into simple decision-making has recognized the frequent dissociation between hypothetical preferences and actual choices (Barlas, 2003). This idea describes the process of informing a choice based on available information, and assessing this choice against anticipated knowledge about the subsequent consequences.

The difficulty that arises here relates to the differentiation between choices, based on a value developed and assigned to the different options, as assessed during the evaluation stage. This process is significantly hindered when there is no prior knowledge or feedback to inform such a value assignment. It is within this limited decision environment that feelings and emotions have been brought back into the discourse.

Some researchers have explicitly identified affect as central in decision processes (Raghunathan & Pham, 1999) and have equated feelings to heuristics (Clore, 1992; Pham, 1998; Schwarz & Clore, 1988), insofar as recognising that they increase in value as a basis for information when decisions are bereft of other judgment processes (Clore, Schwarz, & Conway, 1994; Strack, 1992). The question that is raised here relates to the extent to which these factors influence decision making in these environments (Mosier & Fischer, 2009), and what is their interaction with other, more informative factors (Loewenstein & Lerner, 2003).

The majority of this research has gathered insight into decision making through experimental set-ups, aimed at controlling for extraneous factors and making it possible to identify and differentiate between key processes. This has contributed immensely to the current understanding of decision making, but an alternative field has emerged from a practitioner-centred perspective, aimed at filling the gaps in understanding around more complex decision-making environments. It is important to understand how research in this area has developed, and where these two approaches meet in relation to the aims of the present research.

NDM

The reality of decisions in the real world is that they arise out of an interaction of environmental influences and influences related to the motivation and goals of the person. It is within this setting that decision-making has been recognised as a complex process, dependent on the unique characteristics of the operational setting and influenced by a number of internal as well as external factors (Klein, Orasanu, Calderwood, & Zsambok, 1993). The complexity of these processes holds the key to understanding how individuals operate in real-world environments. And in order to have a clear idea of what this entails, our focus here will be on some of the main factors and what have been termed *wicked* problems.

The concept of wicked problems was proposed in the context of social policy, where a lack of clear definition and competing agents add to the complexity of the task (Rittel & Webber, 1973). The main challenge remained the clear definition of the problem, seeing as most other stages to solving it depended on this premise. Further, the fact that no idealised system could be applied to these, made the basic application of models and heuristics impossible. Work in this area was advanced within the fields of design (Rittel, 1988; Stolterman, 2008), systems engineering (Sølvberg & Kung, 1993) and economics (Hogarth, 2001). On a more general level, defining characteristics of wicked problems have been identified as follows (Conklin, 2005):

1. The problem is not understood until after the formulation of a solution.
2. Wicked problems have no stopping rule.
3. Solutions to wicked problems are not right or wrong.
4. Every wicked problem is essentially novel and unique.
5. Every solution to a wicked problem is a 'one shot operation'.
6. Wicked problems have no given alternative solutions.

The key characteristics in this case relate to the fact that there are no clear solutions, as the outcome is dependent on the particular course of action selected. Coincidentally, once a solution is implemented, the problem will be different the next time around, making each iteration of the problem to some extent unique and novel. Thus, decisions are only evaluated as being right or wrong after the resolution and identification of the outcome. It is the combination of the naturalistic setting and the formulation of these characteristics where the definition of problem-solving steps beyond traditional decision making theory, and requires the inclusion of a number of external factors, in order to be understood in terms of processes at play.

Individuals tasked with solving these problems often operate in dynamic and fast-paced environments, where the setting brings added stresses to already complex situations. Beyond simply defining these as stressing factors in the traditional sense (Janis & Mann, 1977; Ivanicevich & Matteson, 1980; Hogan & Hogan, 1982), the definition which best matches these type of problems defines stress in these environments as the "*process by which certain environmental demands ... evoke an appraisal process in which perceived demand exceeds resources and results in undesirable physiological, psychological, behavioral and social outcomes*" (Salas, Driskell, & Hughes, 1996; p. 6).

They main stressors identified in these environments include the high risk of negative outcomes, changing conditions, time constrains, and uncertainty and ambiguity (Cannon-Bowers & Salas, 1998). Within these settings, individuals still need to gather, process, integrate and act on the data available, in order to inform their decisions. One of the key factors that describe these problems is the notion of uncertainty, which is a defining characteristic of human performance in NDM environments (Fiore, Rosen, & Salas, 2011). It builds on the fact that the available information does not provide sufficient details on which to construct expectations, as described in wicked problems, while the operational settings still require a commitment from the decision maker. This uncertainty is further amplified by these extraneous factors, surrounding performance pressure (Lerner & Tetlock, 1999), which add to the cognitive load of the task. Individuals operating in these environments are also extremely susceptible to anticipated regret (Zeelenberg, van Dijk, Manstead, & van der Pligt, 2000) and emotional affect (Loewenstein & Lerner, 2003).

The other key aspect relates to the processing of task-relevant information. Traditional decision-making models have focused on decomposing the problem into its elements, making it possible to assess them based on rational choice frameworks (i.e. subjective expected utility theory, multiattribute theory, Bayesian inference). Despite the validity and application of these models in a number of fields, they fall short in being validated in these naturalistic environments (Collyer & Malecki, 1998). On the one hand, they require a relatively long time in order to identify problems and assess judgements necessary to develop solutions. On the other, the explicit judgements used in these models are artificial and fail to incorporate implicit and dynamic considerations. So it is precisely the variation in information, in terms of its contribution to the uncertainty of the situation and the ambiguity of the delivered insight, which forms a key part of the factors it adds to the decision-making environment.

As a result of these unique characteristics, both in terms of naturalistic decision-making environments and the operational constraints identified within them, the emphasis has shifted towards decision delay or complete inertia. Research in this area has not focused on what could be termed ‘erroneous decisions’ – seeing as the complexity and ever-changing dynamics of these problems make it difficult to classify decisions as such – and have rather looked at incidences where individuals delay or fail to make a decisions altogether. This applies particularly in these environments, as individuals have to choose between two equally (un)attractive options (Lipshitz, 2005), while operating under a high level of pressure and uncertainty, creating a sense of doubt that blocks or delays action (Lipshitz & Strauss, 1997). Individuals engage in uncertainty management in naturalistic decision-making environments (cf. Fiore, Rosen, & Salas, 2011), but research has shown that the overwhelming conditions and uncertainty often prevent them from applying an effective strategy, resulting in them not making any choice (Anderson, 2003). Similarly, the active need and desire to reach a resolution has also been shown to result in so-called ‘seizing and freezing’ (Kruglanski & Webster, 1996). This becomes a major issue especially when dealing with wicked problems in dynamic environments, where the need to decide is essential in order to further advance and gather more information. So it is this ultimate failure to operate which we aim at identifying, combining knowledge around affective decision-making and information processing, in these unique environments.

2. Neuroscience

A number of sub-disciplines have emerged, each addressing the various influencing factors and taking stock of the varying results. The main approach here is to use a simplified model of decision making, taking into consideration the key factors identified within NDM environments, to identify cognitive processes on a fundamental level. Part of the challenge, as highlighted above, has been to identify the right models to describe decision making in particular environments. The aim here lies in looking at those models from a different perspective, as most of the current insight into decision making has largely been based on qualitative and observational research. The goal is to go further in our understanding, using the current advances in cognitive neuroscience, to develop a more fundamental model of the processes at play. Significant inroads have been made in terms of the emerging field of decision neuroscience (Shiv, Bechara, Levin, Alba, Bettman, Dube, Isen, Mellers, Smidts, Grant, & McGraw, 2005; Gold & Shadlen, 2007), and it is important to see how this has included ideas from social neuroscience and neuroeconomics.

Social Neuroscience & Neuroeconomics

Closely aligned to the ideas within social psychology, the interdisciplinary field of social neuroscience is devoted to the inclusion of neural, hormonal, cellular, and genetic mechanisms, while looking at the associations and influences between social and biological levels of organisation (Cacioppo, Berntson, & Decety, 2010). The aspect most relevant in this case is the integration of biological and psychological explanations of social behaviour (Harmon-Jones & Winkielman, 2007; Harmon-Jones & Beer, 2009). One key notion is the idea of bidirectionality and correlation, where it is important to emphasise the understanding of how the brain influences social processes as well as how social processes can influence the brain (Harmon-Jones & Devine, 2003). It is this complimentary approach, and its insight into neurocognitive mechanisms that give rise to social behaviour, which have driven the surge of interest in social neuroscience (e.g., Cacioppo, Visser, & Pickett, 2005; Harmon-Jones & Winkeilman, 2007). Further, as highlighted, this emerging field benefits from adding a neurobiological approach to social psychology, identifying the fundamental substrates and correlates, using a multilevel analytical approach (Cacioppo & Berntson, 1992).

It is from within this framework that questions have been raised about the cognitive processes at play during decision-making problems. Significant advances have come from the field of neuroeconomics (McCabe, 2003), focused on applying brain-based methods and theories to account for economic decision-making (Loewenstein, Rick, & Cohen, 2008; Glimcher, Camerer, Fehr, & Poldrack, 2008). This has been in line with proposals from TDM, looking at decisions that require allocation of resources (e.g. time) or an assignment of value (e.g. neural value, preferential judgement).

The goal here, based on similar arguments presented above in terms of the validity of TDM models to NDM environments, is to expand the methodological propositions where traditional heuristics fail to fit the operation constraints. Further, the insight in the environments is aimed at non-prescriptive explanations about how individuals do make decisions, rather than on how they should make them. The emphasis here is on the strong inclusion of social elements, which come to the forefront when evaluating decision environments and alternatives. On the simplest level, the goal is to look at the interaction of individuals' emotional response and their immediate goals (McClure, Li, Tomlin, Cypert, Montague, & Montague, 2004), advancing work on preferential judgement and competition between immediate and delayed rewards (McClure, Laibson, Loewenstein, & Cohen, 2004). The bottom line is that these studies look at decisions that arise out of an interaction of the environmental influences (bottom-up: emotions) and influences related to the motivation and goals of the individual (top-down: information), while constructing a neural model of their interaction (cf. Knutson & Peterson, 2005).

3. Methodology

3.1 References from Executive Functions

In order to identify decisions on a neurological level, it is important to be aware of what processes one is observing. Being part of high-order processing, situations involving planning or decision-making, involving error correction or trouble-shooting, requiring responses to novel actions, requiring dangerous or difficult judgements, or requiring overcoming strong habitual response or resisting temptation, have all been recognised to involve executive functions (Norman & Shallice, 1986). These are identified as complex responses, by which individuals optimise their performance in situations that require the operation of a number of cognitive processes (Baddeley, 1996). This results in instructions about which regions of the brain to activate, generally coordinating their synchronised activity (Goldberg, 2001). So it is these functions that are of interest in decision-making processes, in terms of their interaction within the brain, focusing on their influence, as well as dictating effects on responses based on the available stimuli and related information.

3.2 Decision-making – Models & Movement

A number of models have been proposed based on neurological insight in relation to these executive functions, and it is worth considering these models and their development, onto which to incorporate factors more closely related to decision-making research. Thus, despite the acknowledged complexity of decision-making, it is necessary to find a reference point from which to identify these processes and the accompanying brain activity. In this case, the best starting point involves considering movement as a choice, based on the idea of goal-driven action, as opposed to automatic movements and functions (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

The original version of the **Supervisory Attentional System (SAS)** model focuses on goal-driven actions (Norman & Shallice, 1986; Cooper & Shallice, 2000), pointing to significant activation in the prefrontal cortex. This region has also functionally been related to responses (i.e. 'willed' action) in conditions in which response was essentially arbitrary or drawn from a set of responses (Frith, Kriston, Liddle & Frackowiak, 1991; Jahanshahi & Frith, 1998). These sets of actions, within more complex environments, are carried out along sets of stored information (termed *schemas*), which provide biasing mechanisms that activate or suppress particular actions or action routines according to current goals (Norman & Shallice, 1986). This model describes the activation of these schemas as the result of the balance between bottom-up processes (e.g. environmental cues, habit) and top-down processes (e.g. task demands, consequential planning). The **revised SAS** is more complex, taking into consideration three separate stages: specifying a new schema, implementing it, and monitoring the results (Shallice & Brugress, 1996).

Aimed at describing the overall control of cognition, the **integrative model** of voluntary choice again places a strong emphasis on the prefrontal cortex (Miller & Cohen, 2001). In this model, the brain region provides biasing signals, enabling novel and non-automatic mapping between sensory inputs (environmental information), internal states (emotional affect), and response outputs (choice). Within this model, research has also highlighted that the prefrontal cortex responds primarily to the rules of the task, rather than the specific stimulus (Asaad, Rainer, & Miller, 1998, 2000); fulfilling the role of goals and plan processing, rather than basic input and information processing.

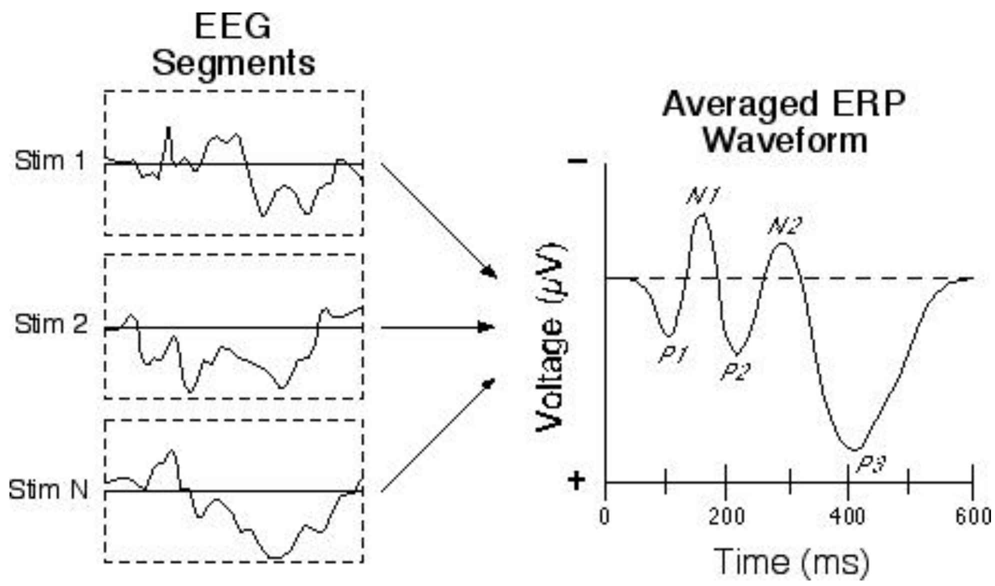
Overall, the question raised at this stage is about the feasibility/validity/possibility of applying these models to decision-making under particular operational conditions. On an epistemological level, it is important to identify if these models of cognitive processing suffice to describe complex processing of executive functions during choice situations. On a higher level, the question emerges as to whether these neurological premises are flawed in terms of their ability to confidently describe cognitive and experiential processes (Rachamandran & Blakeslee, 2005; Panksepp, 2008). Both of these concerns are acknowledged in our approach, which aims at addressing these from a new perspective, based on current methodological advances.

3.3 ERPs from EEGs

To gain a valid insight into these processes, it is important to maintain a good time resolution, as the focus is on the effect of high-pressure and uncertain environments have on decision making, as a combination of the factors identified from within NDM. Experimentally, the emphasis is on the particular time-intervals where these changes are present in individuals’ responses to these fast-paced situations, and how they are further reflected when referenced against behavioural measures. For this purpose, the best approach for this involved taking electroencephalographic recordings, with the view on identifying key evoked-response potentials.

Electroencephalographic (EEG) waveforms reflect neural activity from all parts of the brain, where some of this activity is related to specific tasks (e.g. visual perception, reading, movement), while most will be related to activity of other neurons, not directly engaged in the task (regarded as background-noise of electrical activity) (cf. Luck, 2005; cf. Handy, 2005). This noise can be accounted for through the repetition of the stimuli, in order to reduce the so-called signal-to-noise ratio. The resulting graphs describe the changes over time (x-axis, in milliseconds) for the electrode potential (y-axis, in microvolts).

Figure 2. EEG Waves and ERP Averages



Recordings provide an insight into brain processing, using EEG as a remote measurement of the electrical potential directly generated by neuronal activity, in the form of signals originating in the postsynaptic dendritic currents, rather than the axonal currents associated with the action potential (Nunez & Srinivasan, 2006). This allows one to study perceptual and cognitive processes, by averaging the electrical activity that is time-locked to particular stimulus categories. Designing a specific decision-making paradigm enables one to observe and quantify complex cognitive processing through a continuous measure (Luck, Woodman, & Vogel, 2000), based on event-related potentials (ERPs), used to describe activity relating to individual stimuli, where these stimuli have been paired with proposed decision-making stages.

ERPs are changes in electrical activity, which can be recorded noninvasively from the surface of the scalp and reflect summated postsynaptic potentials from large sets of synchronously-firing neurons (Allison, Woods, & McCarthy, 1986; Fabiani, Gratton, & Coles, 2000). The identified ERPs are important to the study of psychological processes, based on the association of individual components with distinct information-processing operations, time locked to sensory, motor, or cognitive events (Gehring, Gratton, Coles, & Donchin, 1992). In these cases, component amplitude is thought to reflect the extent to which the associated psychological operation has been engaged with, and latency of the component's peak is thought to reflect the point in time by which the operation has been completed (Ito, Willadsen-Jensen, & Correll, 2007).

For the purposes of identifying decision-making processes under these conditions, ERPs not only offer an excellent temporal resolution, but are also useful in assessing both explicit and implicit processes. This is particularly true of the latter, as they are recorded without informing participants of what is being assessed or requiring them to accurately or honestly report their responses (cf. Greenwald & Banaji, 1995). This is especially true when trying to find subtle differences, especially for components occurring early during processing, where the influence of information manipulation and response strategies is less likely. Finally, although the spatial resolution of ERPs is lower than that of techniques such as fMRI and PET, the scalp distribution of observed activity can be used to obtain estimates of neuroanatomical location of the source of activity, based on 3-dimensional source modelling.

Seeing as the emphasis is on identifying decision-specific ERPs, in line with the recognised decision-making stages, the reference was taken from movement-specific components. Recordings in these instances focused on the *Bereitschaftspotential* (readiness potential), identified as activity prior to a movement (Shibasaki & Kato, 1975; Boschert, Hink, & Deecke, 1983). These potentials have been shown to appear as negative shifts prior to the movement over the primary sensorimotor areas (Kornhuber & Deecke, 1965; Deecke, Scheid, & Kornhuber, 1969; Kristeva, Keller, Deecke, & Kornhuber, 1979). Considering the fast response times for some of the conditions, the emphasis has also been on the negative slope (*NS'*), observed as the steepest part of the negative shift prior to the onset of muscular contraction (Shibasaki, Barrett, Halliday, & Halliday, 1980).

The overall idea is to simplify the decision-making implementation, relying on choices as voluntary movement, accounting for any variations in terms of oral or written commitment to an alternative. Further, the focus in this situation is not on the specificity of a choice, but on the making of a decision (deliberation) and the final commitment to it (implementation). This framework allows capturing any changes in terms of urges to move, as observed for participants who may not be fully committed to act and may still be able to suppress the action, as part of a late-checking mechanism (Brass & Haggard, 2007). Similarly, the translation of mental decisions into motor-responses allows for experimental confirmation based on lateralisation of readiness potentials (Haggard & Eimer, 1999), as well as activity linked to planning, preparation and movement (Passingham, 1996; Ball, Schreiber, Feige, Wagner, Lϋcking & Kristeva-Feige, 1999).

So the basic premise advanced here follows on from our basic decision-making stages, identified through perception and movement related components within EEG measures, aimed at identifying these as individual processes. This mirrors the overall ethos of social neuroscience, as the application of knowledge about brain and body gained from cognitive measurements, in order to develop new theories of basic mechanisms, resulting in a more complete understanding of psychological and behavioural process (Harmon-Jones & Beer, 2009). Furthermore, whereas traditional research on social cognition and motivation has had to infer the activity of underlying cognitive mechanisms only by the proxy of behavioural expressions (e.g., on reaction-time tasks), ERPs and other neuroimaging methods allow researchers direct access to the cognitive machinery that drives social behaviour, thereby providing a powerful tool for testing theories of social cognitive and motivational processes (Bartholow & Amodio, 2009). These ideas expand on early suggestions that we should try and bring real-world problems to an experimental setting to assess their cognitive make-up, in an attempt to improve our understanding of cognition in the wild (Hutchins, 1995). While this particular paradigm does not claim to provide an exhaustive description of real-world decision making, it will further contribute to the emerging models of cognitive architectures (Taatgen & Anderson, 2009), aimed at providing predictive descriptions and overall identification of individual processes and their relationship in particular tasks.

4. Contribution

The main goal is to further contribute to the current understanding of decision-making processes in forced-choice environments. This contribution is based on recent developments in the field of cognitive neuroscience, adding insight through the use of EEG measures, as a way of isolating key factors relating to information processing, deliberation and implementation of decisions. We will look at if, and how, behavioural responses and cognitive measures interact when making decision, in environments characterised by ambiguous information and high-risk conditions, as prescribed by the operational limitations.

The goal here is not to provide an exhaustive description of cognitive and neurological processes within naturalistic decision-making environment, but to establish a valid framework in which to continue expanding on fundamental models of decision making.

5. Chapter Outline

The rest of the PhD dissertation is structured around the five different experiments carried out. Each experiment is described in an individual chapter (Chap. II – VI), focusing on a specific introduction, and information on methodology and results. These are then discussed in detail for the particular experiment. Finally, all of these results are discussed in the last chapter (Chapter VII), in order to draw final conclusions from the findings, before moving on to the overall research contributions and implications for the proposed hypotheses.

Chapter II

Experiment 1: lack of information, on which to base deliberation and decision; only emotional-consequences available to base references on.

Chapter III

Experiment 2: addressing questions raised in Experiment 1, to see if higher cognitive loading (merging) influences the behavioural response.

Chapter IV

Experiment 3: addressing questions raised in Experiment 1, to see if confidence manipulation (mood setting) influences the behavioural response.

Chapter V

Experiment 4: information provided, to inform the deliberation and decision; based on advice manipulations in relation to the Reverse Stroop Effect.

Chapter VI

Experiment 5: information provided, to inform the deliberation and decision; based on advice manipulations of unclear information.

Chapter VII

General discussion and conclusions, drawing together findings from all experiments.

Chapter II

Emotional Influence

Experiment 1

1. INTRODUCTION

This study examined individuals' decision-making processes in an experimental environment characterised by an absence of information, time pressure and risk. Not uncommonly, decision makers have to make rapid decisions where aversive outcomes are inevitable but task specification is ambiguous and more information (ideally) would be forthcoming but ultimately is not available. For example, 'Do I, or do I not, deploy paramedics to injured victim X in terrorist scenario? If I do deploy and there is another device I could be risking further loss of life. If I do not, I run the risk of losing the currently injured victim'. Alison, Humann, and van Den Heuvel (2011) have described these high risk binary choice decisions as 'damned if I do or don't decisions' and argued that they are especially difficult because both options look aversive and there is no capacity for further useful information upon which to develop a sufficiently clear situational model that would help lead to a more informed decision. As such, no matter which decision is taken, it could lead to a bad outcome.

The objective of the current paper is to establish: (i) whether we can discriminate distinct decision phases throughout these sorts of tasks and (ii) whether a manipulation of the seriousness of the outcome (bad consequences) affects these phases. The paper proposes that, by reference to behavioural (timing) measures, EEG and verbal feedback from participants after the task that the following distinct phases will emerge: evaluation (of task), deliberation (of options) and implementation (of action). We argue that distinct phases will emerge and that although deliberation is redundant (i.e. it does not help solve the task) individuals will still consider options and seek to ‘solve’ the task. We argue that this will be especially pronounced in the high consequence conditions and that there will be greater urgency to implement action.

1.1 Phases of Decision Making

Decision making is defined as “the process commonly portrayed as occurring early in the ‘problem-solving process’ - the sensing, exploration, and definition of problems or opportunities - as well as the generation, evaluation, and selection of solutions” (Huber & McDaniel, 1986; p.576). However, there has been little effort to establish the cognitive activity associated with these proposed shifts from evaluation - deliberation - implementation (Gollwitzer, Heckhausen, & Steller, 1990) or options, evaluation, and choice (Herrnstein & Prelec, 1991; Baron, 1994; Lipshitz, Klein, Orasanu, & Salas, 2001).

Some researchers have explicitly identified affect as central in decision processes (Raghunathan & Pham, 1999) and have equated feelings to heuristics (Clore, 1992; Pham, 1998; Schwarz & Clore, 1988), insofar as recognising that they increase in value as a basis for information when decisions are bereft of other judgment processes (Clore, Schwarz, & Conway, 1994; Strack, 1992).

1.2 Cognitive Processes

As the emerging field of decision neuroscience has made large strides in advancing ideas around individual cognitive processing (see Shiv et al., 2005, and Gold & Shadlen, 2007, for reviews), it has been less committed to incorporating those factors relevant to deliberation and implementation of decisions, and how these are reflected in brain activity. Considering the particular decision-making phases described above, the proposed focus was on the observation of movement-related potentials in the supplementary motor area (Kornhuber & Deecke, 1965; Shibasaki, Barrett, Halliday, & Halliday, 1980; Kawashima et al., 1995) and early activity, known as the Bereitschaftspotential (Shibasaki & Kato, 1975; Boschert, Hink, & Deecke, 1983). Both of these were regarded as indicators of decision deliberation and, ultimately, commission to a choice, as fundamental reflections of movement-commission. The emphasis was on changes in source activation, analysing the phases of voluntary preparation and execution.

Research has repeatedly shown that large, positive slow-waves of event-related potentials (ERP) reflect the allocation of more attentional resources in cases of motivational significant stimuli (Hamm, Schupp, & Weike, 2003). Further, results have consistently described these affective evaluations as routine processes involved in virtually all processes of perceptions (Cacioppo, Gardner, & Bernston, 1999). The basic premise here followed on from the notion that emotional tasks result in prolonged periods and elevated intervals of brain activity, as more cognitive resources are necessary to assess situations.

This is linked to the idea that emotional experience is a by-product of neural computations associated with processing of value-laden stimuli (LeDoux, 1996). Thus, extensive visual cortex activity has been recorded when participants view emotional pictures (Bradley et al., 2003). Further, the anterior cingulate cortex plays a role in representing subjective emotional responses, which has also been found to be consistent with a suggested role for associated medial prefrontal structures in representing states of mind (Lane, Fink, Chau, & Dolan, 1997). The expectation thus follows on from the idea that emotional-laden information will result in increased cognitive activity at a visual as well as an affective processing level.

1.3 Objectives and Hypotheses

The goal was to use a simplified decision paradigm, characterised by lack of information and varying levels of consequence threat, to identify the different phases within the proposed decision-making model. These factors provided the grounds to establish how individuals were affected by the potential consequences of their choices and whether they engaged in (redundant) deliberative processing before implementing their decisions. The following objectives were also considered:

> To identify the neural processes involved at each stage of decision-making (evaluation, deliberation, pre-implementation, and implementation).

> Emotional stimuli that suggest more significant and consequential outcomes will result in increased and prolonged amplitudes at the stages of deliberation, preparation (frontal lobe and cingulate cortex) and implementation (parietal lobe).

> In the overt absence of any information on which to deliberate individuals will show neural signs associated with deliberation (which from a purely rational perspective is redundant).

> Reaction time associated with deliberation and implementation in forced choice tasks is affected by the emotional conditions, resulting in delay for significant and consequential outcome scenarios, as the decision threshold is reached later.

2. METHOD

2.1 Participants

Fourteen individuals (9 females, 5 males) participated in the study. They ranged in ages from 21 to 34 years, with a mean age of 27 years. Participants were drawn from a sample of psychology students, all without any disclosed health issues, and were all right-handed.

2.2 Procedure

Participants were presented with task-related information on a computer screen, and they used a mouse placed below their right hand to give their responses. The experiment consisted of a series of decision situations, at the end of which individuals were asked to make a choice between two random alternatives under time pressure. The task consisted of a 'bomb scenario', where participants were asked to imagine themselves operating in the various scenarios and where the objective was to 'cut' the correct of two wires to disarm a bomb. Following this, they faced a decision stage and had to choose between two alternatives, in the form of two different-coloured wires (see *Table 1*) (failing to do so, automatically led to 'detonation'). The basic premise of the decision problem focused on a binary negative outcome paradigm, where participants had to choose between two arbitrary alternatives, not knowing which would be the correct wire - reinforced through time constrains and performance pressures - and where a 'wrong' decision lead to a negative outcome.

First, they were presented with a context-setting scenario involving either:

(i) a light-bulb, which they had to switch off by picking a wire (low consequence condition),

(ii) an industrial courtyard, in which the wires were used to disarm a bomb (medium consequence condition), or

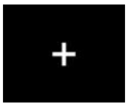
(iii) children on a playground, in which the wires were used to disarm a bomb (high consequence condition).

In summary then, the stimulus indicated one of three conditions: 1) low consequence, 2) medium consequence, and 3) high consequence. This was followed by an image of a light switch (low consequence condition) or explosive device (medium- and high-consequence conditions), to reinforce the situational context. Finally participants were prompted to choose between a red or blue wire ‘connected’ to the particular device. Failure to make a decision or a wrong one, led to detonation of the device. Following each choice, they received feedback in the form of a “*CORRECT*” or “*INCORRECT*” on-screen message.

The instructions, prior and during the experiment, all emphasised the need to take quick and decisive action. Participants were told that they would be assessed on their accuracy as well as their speed, forming part of an overall learning task. What participants did not know, was that the order and number of correct or incorrect decisions was set prior to the experiment, and they had no influence on the decision task. This was done in order to maintain a uniform pattern across participants. A total of 180 stimuli series were presented in two blocks, with a 5 minutes break between them. Each block also contained 3 interludes, where participants were presented with a progress report about their performance so far. All of these reports contained the same information about mistakes made so far, stating that they had been performing “*below average”* and reinforcing the need for them to take decisive and quick action, as well as the need to improve their performance and accuracy.

After the task, participants provided some demographic information (e.g. gender, age) and completed a picture-rating task, based on the scenario images they saw during the experiment. They were asked to rate each picture, based on how emotional they found the image (3-point Likert scale: *Neutral*, *Low*, or *High*), and then on the perceived affect if their choice resulted in a negative outcome (7-point Likert scale: 1. *Not-at-all,* to 7. *Extremely Affected*) (see *Appendix A*). These ratings gauged the perceived emotionality of pictures and provided a measure of internal consistency between the conditions and the paradigm’s effectiveness, resulting in a post-test validation of the different scenarios. After this, participants completed a brief open-ended questionnaire about their performance, their individual strategy and their focus during the task, and three different scales after the rating task. These included Barratt's Impulsivity scale (Patton, Stanford, & Barratt, 1995), the Regulatory Mode Concerns (Assessment-Locomotion) scale (Higgins, Kruglanski, & Pierro, 2003), and the Need for Closure scale (Kruglanski & Webster, 1996) (see *Appendix B*). Finally, they were debriefed about the research and the pre-determined task conditions. The whole experimental procedure took a maximum of 1 hour and 30 minutes for each participant.

<u>*Table 1.*</u> Decision Paradigm

Stage		Evaluation	Deliberation	Choice	
Stimuli	Mask	Context	Device	Decision	Feedback
					CORRECT or INCORRECT
TIME	*2,000ms*	*2,000ms*	*2,000ms*	*3,000ms*	*1,500ms*

2.3 Recordings

EEG was recorded using 64 electrodes in continuous mode on Biosemi (ActiView v6.05, Amsterdam – Netherlands). A band pass filter of 0.16-100 Hz and a sampling rate of 500 Hz were used, while the electrode-to-skin impedance was kept below 5 kΩ. Elecrooculography (EOG) measures were recorded, using electrodes placed above and below the left eye, while electrocardiographic (ECG) measures were recorded by placing one electrode on the right ankle and another one on the left wrist. Both of these recordings were used to account for any artefacts in the data analysis. The decision scenarios were designed using Inquisit (Millisecond Software v3.0.4, Seattle – USA), and recordings for each participant's reaction times were matched with the particular triggers included in the task stages.

2.4 Data Analysis

Averaged EEG epochs were segmented after band pass filtering and analyzed using the Brain Electrical Source Analysis (BESA) program (MEGIS Software, Munich – Germany). Trials containing ECG artefacts or large EOG variations (> 75 mV) were discarded from further analysis. For the vision-related measures, 2,269 averaged EEG epochs were segmented to a length of 1,100 ms (100 ms pre- to 1, 000 ms post-stimulus). For the movement-related measures, 2,264 averaged EEG epochs were segmented to a length of 2,000 ms (1,500 ms pre- to 500 ms post-stimulus). A source model of the EEG potentials was constructed from the grand average data (N = 14) for each of the measures. The data were transformed into the Talairach coordinate system, and the locations of the EEG sources were evaluated for each individual source dipole (Talairach Client v2.4.2, Research Imaging Centre, UTHSCSA - USA).

2.5 Statistical Analysis

The effect of stimulus intensity on the dipole source was analyzed using an analysis of variance (ANOVA), where the recordings within the participants were compared, for the movement processing. The independent variables were the three different scenarios (low-, medium- and high-consequence). Pair-wise comparisons were carried out between the three scenarios, and a 95% confidence level was used throughout.

3. RESULTS

Results will detail the two parts of the experiment. First, the focus will be on the perception components within the EEG recordings, describing the differences in amplitudes for each of the source dipoles directly following the presentation of the scenario context stimuli. Secondly, the focus will be on the movement component of the EEG recordings, describing the differences in amplitudes for each of the source dipoles prior to the commission to a particular choice. Data for the response times were also considered at this stage, to gain a fuller picture of the relationship between cognitive and behavioural processes. For both of these recordings, the data will be compared based on the three scenario conditions, looking for significant differences in the source waveforms.

3.1 Perception-related components

Five regional source dipoles were fitted to describe the 3-dimensional source currents contributing to the data (see A, in Figure 1). Three sources were located in the occipital lobe. The central source (S1, Talairach coordinates in mm [8, -82, 19], Brodmann area 18), peaked at 170 ms. Two secondary sources, occupying lateral locations, ($S2_L$ [-41, -99, -23] and $S3_R$ [42, -81, -12]) peaked at 184 ms and 176 ms respectively. Two other sources were located in the parietal lobe. One source was located contralateral to the movement hand (S4 [-13, -46, 24], peak 258 ms), while the other source was located ipsilateral to the hand (S5 [39, -40, 39], peak 550 ms). The grand-average model was tested for all conditions, and the residual variances were similar in all conditions (all 23%, low-consequence 18%, medium-consequence 11%, high-consequence 17%) (see B, in Figure 1).

To evaluate the differences between the three scenario conditions, individual source waveforms for each were obtained using the grand-average model. The average source waveforms with time intervals showing statistically significant deviation ($p < 0.05$) between the different conditions are show in Figure 1.

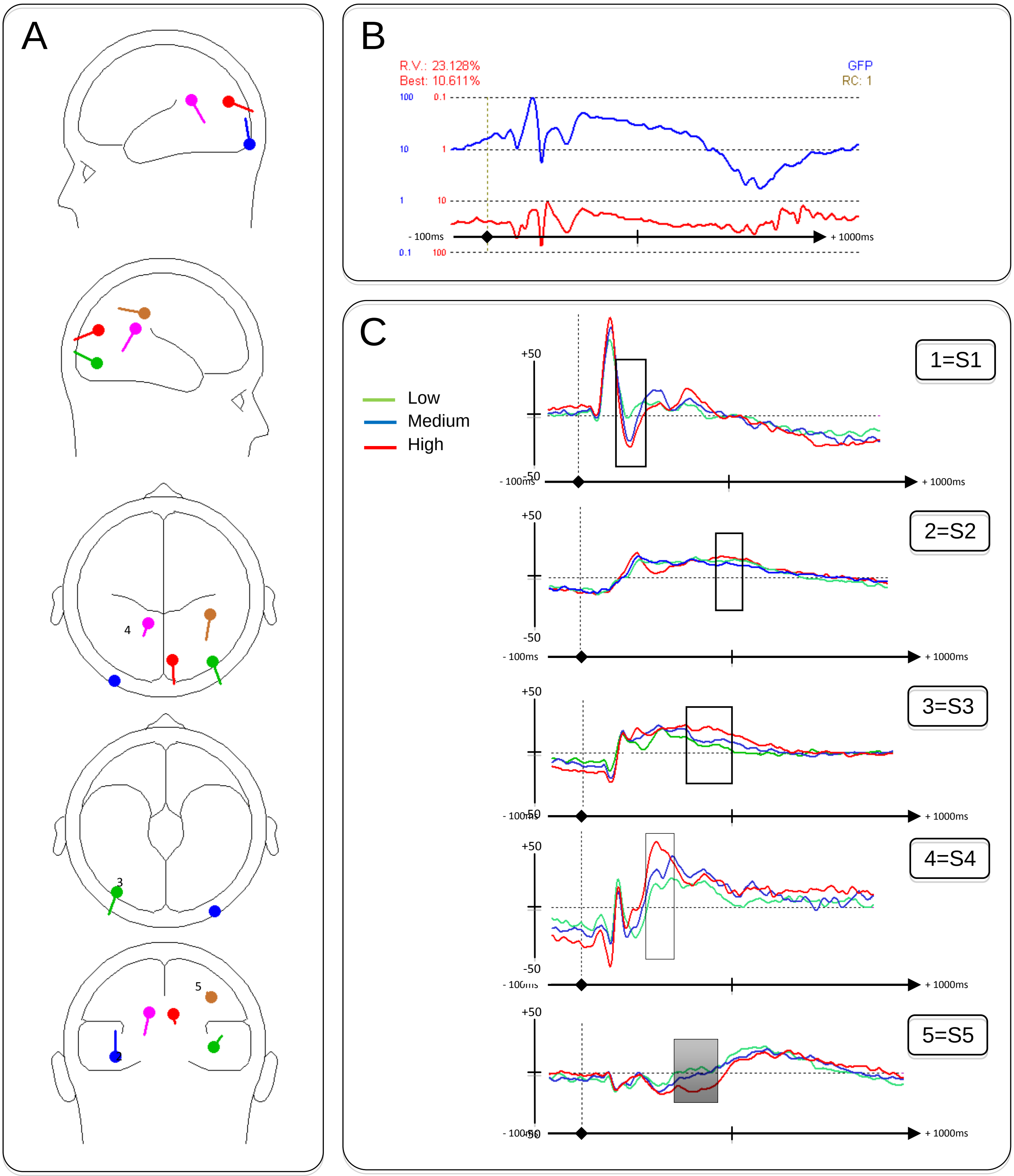
Scenario conditions were associated with statistically significant differences of source dipole amplitude in the S1 source (time interval: 100 ms to 240 ms), *F* (2,

26) = 6.6, *p* = .005), with post-hoc tests showing that high-consequence scenarios (*M* = -8.38, *SD* = 45.52) resulted in a larger decrease in amplitude than low-consequential ones (*M* = 12.41, *SD* = 25.23), *F* (1, 13) = 9.5, *p* = .009. Similar significant differences were observed at both lateral source dipoles (S2 & S3) located in the occipital lobe, when looking at later time intervals. In this case, amplitudes for the contralateral source dipole (S2) showed a significant difference (400 ms to 500 ms), *F* (2, 26) = 17.4, *p* = .000, with post-hoc tests showing that high-consequence scenarios (*M* = 26.94, *SD* = 11.82) resulted in a slower decrease in amplitude than did low-consequence ones (*M* = 19.52, *SD* = 10.17), *F* (1, 13) = 20.8, *p* = .001). Similarly, amplitudes for the ipsilateral source dipole (S3) showed a significant difference (300ms to 500ms), *F* (2, 26) = 22.9, *p* = .000), with post-hoc tests showing that high-consequence scenarios (*M* = 30.74, *SD* = 19.81) resulted in a slower decrease in amplitude that did low-consequence ones (*M* = 9.72, *SD* = 15.88), *F* (1, 13) = 30, *p* = .000.

Analysis for both source dipoles in the parietal lobe showed again significant differences between the scenarios conditions. There were statistically significant differences between the amplitudes recorded at the contralateral source (S4) (200 ms to 300 ms), *F* (2, 26) = 38.4, *p* = .000, with post-hoc tests showing that high- (*M* = 92.99, *SD* = 51.84), *F* (1, 13) = 54.2, *p* = .000, as well as medium-consequence scenarios (*M* = 61.02, *SD* = 40.71), *F* (1, 13) = 19.2, *p* = .001, resulted in a larger increase in amplitude than low-consequence ones (*M* = 33.4, *SD* = 47.01). On the other hand, the ipsilateral source (S5) also showed significant differences between the amplitudes (290 ms to 390 ms), *F* (2, 26) = 15.3, *p* = .000, but these pointed towards a larger increase in amplitude for the low-consequence scenarios (*M* = 23.19, *SD* = 14.24) than for the high-consequence ones (*M* = 2.71, *SD* = 18.31), *F* (1, 13) = 23.9, *p* = .000).

<u>*Figure 1.*</u> *Perception Components*

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Occipital Lobe; 3 = S3 Occipital Lobe; 4 = S4 Parietal Lobe; 5 = S5 Parietal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each scenario condition overlaid (low-consequence = green; medium-consequence = blue; high-consequence = red). Empty rectangles indicate statistically significant (*p* < .05) increase for source amplitudes in more consequential scenario conditions, while filled rectangles indicate statistically significant (*p* < .05) decrease for source amplitudes in more consequential ones. Numbers of source waveforms correspond to (A).



3.2 Decision Components

3.2.1 Movement-related components

For the analysis five regional source dipoles were fitted to describe the 3-dimensional source currents contributing to the data (see A, in Figure 2). One source was located in the cingulate cortex (S1 [-8, -25, 37]), peaking at -313 ms before the decision was. Two other sources were located in the parietal lobe. One source was located contralateral to the movement hand (S2 [-28, -34, 64], peak -65 ms), while the other source was located ipsilateral to the movement (S3 [13, -84, 42], peak 156 ms). Two more ipsilateral sources were identified, one located in the frontal lobe (S4 [55, 29, 27], peak 225 ms), and a last one located in the ventral posterior lobe (S5 [34, -82, -23], peak 102 ms). Again, the grand average model was tested for all conditions, and the residual variances were similar in all conditions (all 18%, no-emotion 25%, low-emotion 25%, high-emotion 21%) (see B, in Figure 2).

To evaluate the differences between the three scenario conditions, individual source waveforms for each were obtained using the grand average model. The average source waveforms with time intervals showing statistically significant deviation ($p < 0.05$) between the different conditions are show in Figure 2. Analysis of the selected Bereitschaftspotential parameters was performed, using a three-way ANOVA for repeated measures. The focus was on particular time intervals, prior to the participants' voluntary movements, identifying their commitment to a particular choice through movement-related potentials (see C, in Figure 2).

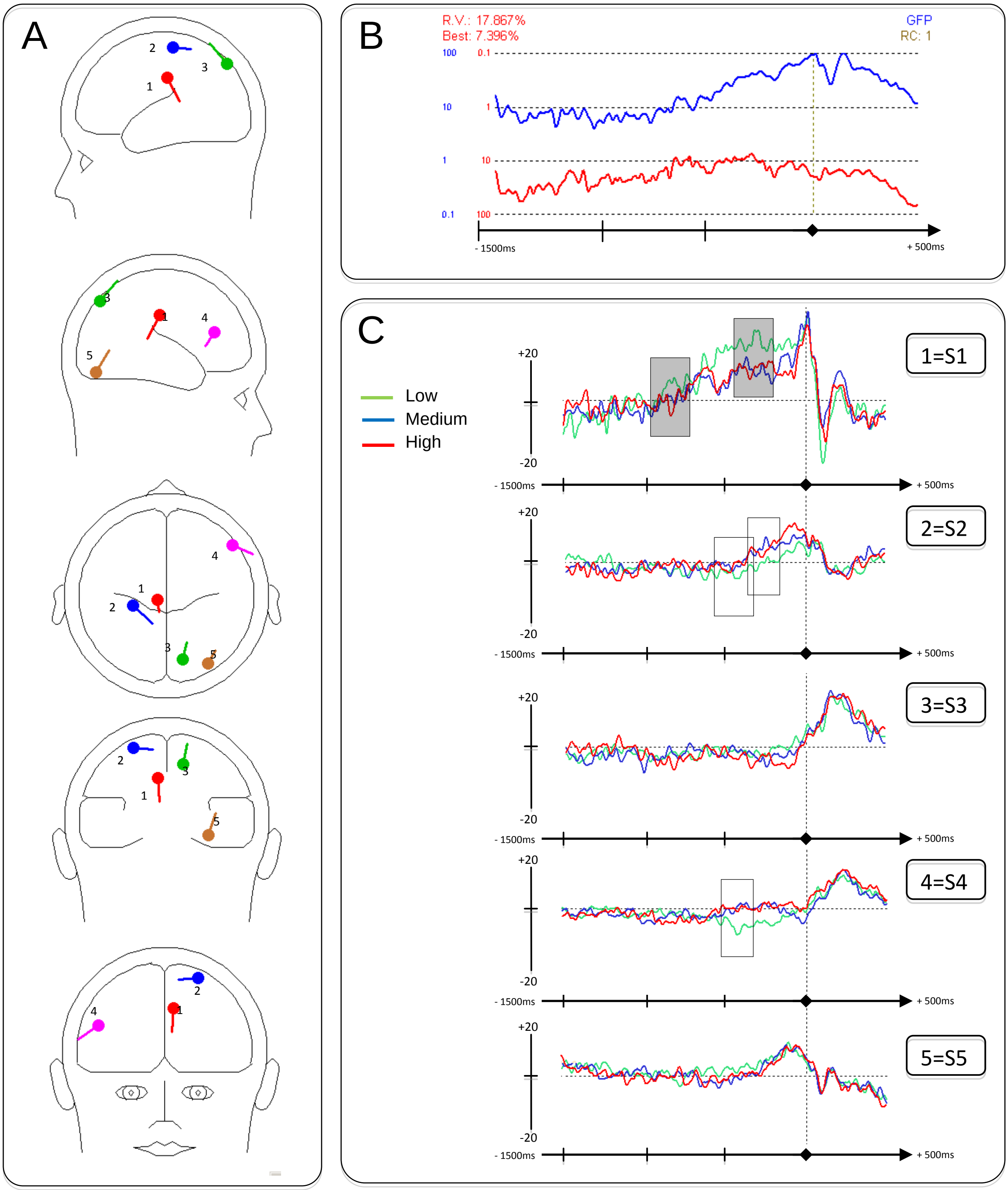
For source S1, scenario conditions were associated with statistically significant differences of source dipole amplitude for two separate time intervals. An early interval (-850 ms to -750 ms) showed a significant difference between the source amplitudes, F (2, 26) = 4.7, p = .018, with post-hoc tests showing that the low-consequence scenarios (M = 23.58, SD = 22.01) resulted in larger increase in amplitudes than did high- (M = 8.39, SD = 19.22), F (1, 13) = 9, p = .010, or medium-consequence ones (M = 9.02, SD = 17.34), F (1, 13) = 5.1, p = .042. A later interval (-350 ms to -250 ms) also showed a significant difference between the source amplitudes, F (2, 26) = 5.1, p = .013, with post-hoc tests showing again that low-consequence scenarios (*M* = 34.05, *SD* = 33.43) resulted in larger increase in amplitudes than did high- (*M* = 17.71, *SD* = 25.86), *F* (1, 13) = 7.8, *p* = .015, or medium-consequence ones (*M* = 14.85, *SD* = 32.46), *F* (1, 13) = 5.6, *p* = .035.

For the source in the contralateral parietal lobe (S2), we selected two overlapping time intervals, to analyse the differences between conditions. An early interval (-450 ms to -200 ms) showed a significant difference between the source amplitudes, *F* (2, 26) = 9.5, *p* = .001, with post-hoc tests showing that the high- (*M* = 8.9, *SD* = 14.07), *F* (1, 13) = 11.1, *p* = .005, and medium-consequence ones (*M* = 10.63, *SD* = 14.11), *F* (1, 13) = 12.3, *p* = .004, resulted in larger increase in amplitudes than did the low-consequence ones (*M* = -2.17, *SD* = 12.18). A later interval (-350 ms to -100 ms) also showed a significant difference between the source amplitudes, *F* (2, 26) = 6.9, *p* = .004, with post-hoc tests showing that the high- (*M* = 12.4, *SD* = 16.54), *F* (1, 13) = 8.5, *p* = .012, and medium-consequence ones (*M* = 12.67, *SD* = 16.61), *F* (1, 13) = 10.2, *p* = .007, resulted in larger increase in amplitudes than did the low-consequence ones (*M* = 0.97, *SD* = 11.3). On the other hand, analysis for the source in the ipsilateral parietal lobe (S3) at the time interval (-220ms to -120) around the pre-movement peak amplitude at -170 ms, showed that there was no significant difference between the three scenario conditions in this particular location.

When looking at the source located in the frontal lobe (S4), we again identified two separate time intervals. An early interval (-450 ms to -350 ms) showed a significant difference between the source amplitudes, *F* (2, 26) = 4.5, *p* = .02, with post-hoc tests showing that the high-consequence scenarios (*M* = 7.01, *SD* = 8.31) resulted in larger increase in amplitudes than the non-emotional ones (*M* = -6.5, *SD* = 17.63), *F* (1, 13) = 7.4, *p* = .018. A later interval (-300 ms to -150 ms) showed no significant difference between the source amplitudes for the three scenario conditions. The last source we looked at was located in the in the ventral posterior lobe (cerebellum) (S5), and analysis on a wider time interval (-480 ms to -280 ms) showed that there were no significant differences between the amplitudes for the different scenario conditions.

Figure 2. *Movement Components*

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Cingulate Cortex; 2 = S2 Parietal Lobe; 3 = S3 Parietal Lobe; 4 = S4 Frontal Lobe; 5 = S5 Posterior Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each scenario conditions overlaid (low-consequence= green; medium-consequence = blue; high-consequence = red). Empty rectangles indicate statistically significant (*p* < .05) increase for source amplitudes in more consequential scenario conditions, while filled rectangles indicate statistically significant (*p* < .05) decrease for source amplitudes in more consequential ones. Numbers of source waveforms correspond to (A).



3.2.2 Reaction Times

When analysing the recorded reaction times, the scenario conditions were associated with statistically significant differences (*F* (2, 26) = 5, *p* = .015), with times for high-consequence scenarios (*M* = 804.48, *SD* = 201.16) being significantly slower than those recorded for medium- (*M* = 876.73, *SD* = 186.49), *F* (1, 13) = 12, *p* = .004, *r* = 0.69, and low-consequence ones (*M* = 904.99, *SD* = 202.97), *F* (1, 13) = 7.1, *p* = .019, *r* = 0.59. Results showed an overall tendency, where the more consequential a presented scenario was, the faster individuals made a decision about their choice of wire to cut. The results for the differences in reaction times were overlaid with the significant differences in amplitudes observed for two of the movement-related sources (see Figure 3). The time differences were of less than 100 ms, with deviations of around 200 ms, which pointed to a very narrow margin of difference between the reaction times for all three conditions.

When looking at the movement-component located in the parietal lobe (S2), the graph showed an inverse trend for the waveform amplitudes in comparison to the reaction times (see A, in Figure 3). While individuals recorded faster times as the consequentiality of the scenarios increased, the recorded activity showed a significant increase in amplitudes for both consequence scenarios, in both selected time intervals.

On the other hand, when looking at the movement-component located in the cingulate cortex (S1), the graph showed a similar trend for the waveform amplitudes when compared to the reaction times (see B, in Figure 3). As individuals recorded faster times with the increase of consequentiality in the scenarios, the recorded activity showed a significant decrease in amplitudes for both scenarios, again in both selected time intervals.

The last movement-component overlaid was the one located in the frontal lobe (S4), for which the graph again showed an inverse trend for the waveform's amplitudes in comparison to the reaction times (see C, in Figure 3). While individuals recorded faster times as the consequentiality of the scenarios increased, the recorded activity showed a significant increase in amplitudes for both scenarios in both the early time intervals. The late interval did not show a significant difference between the conditions.

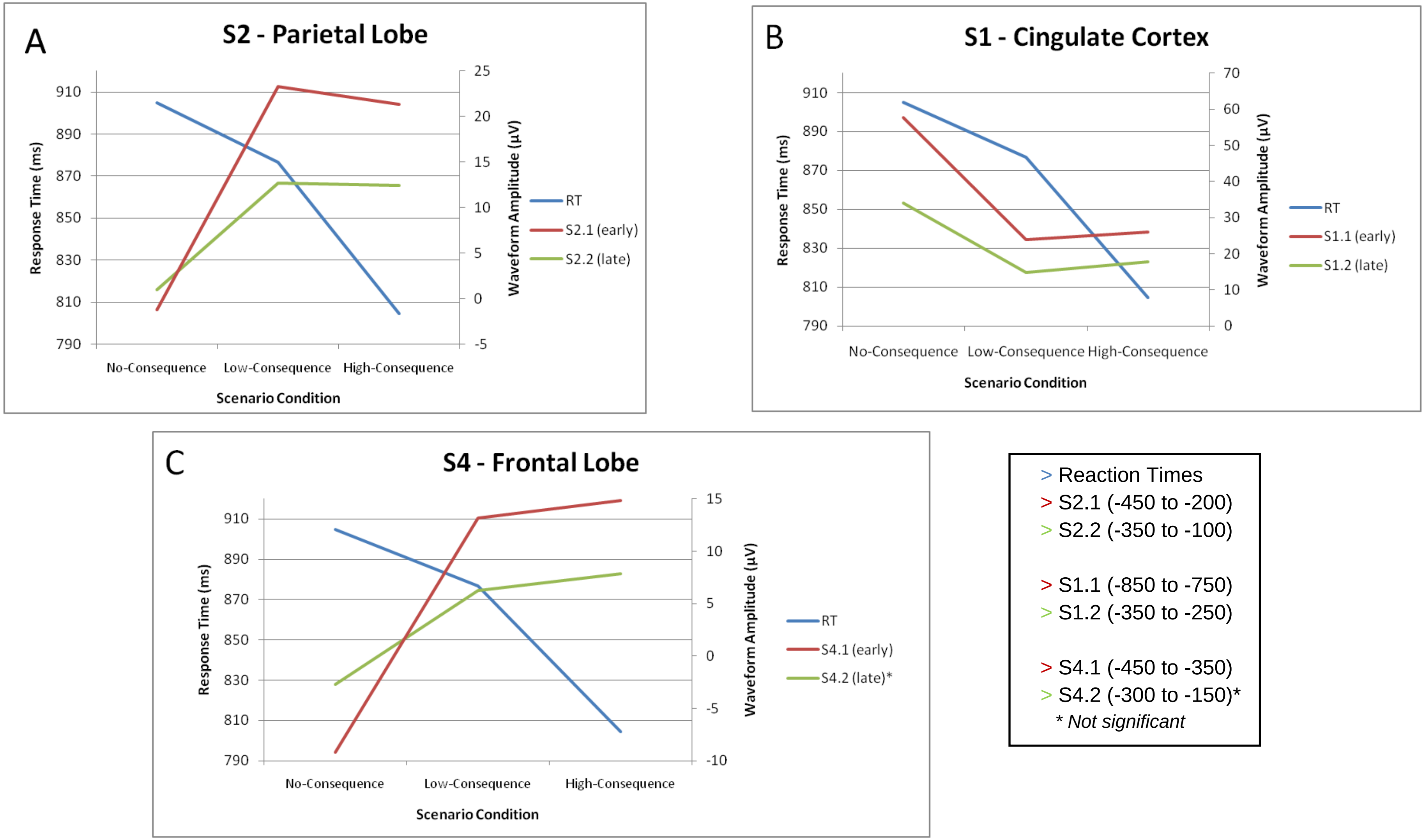
3.3 Ratings

Further, to look at the relationship between the different scenario conditions and the various measures taken, correlations were carried out based on the individuals' picture ratings. Ratings were significantly different across all participants, for both the measure of how emotional they perceived the scenario to be (F (2, 26) = 74.6, p = .000), as well as how affected they would have felt if they made a wrong decision (F (2, 26) = 110.7, p = .000). For the emotionality ratings, results showed that, overall, the images were classed into the specific scenarios as predicted. Also, in terms of the affect ratings, the results revealed that the high-consequence scenarios were given a significantly higher emotionality rating (M = 6.39, SD = 1.12) than the medium- (M = 2.83, SD = 0.69) and low-consequential ones (M = 2.02, SD = 0.99), F (1, 13) = 444.5, p = .000). It should be noted, that although the analysis pointed to a significant difference between the medium- and low-consequential scenarios, both mean scores were very similar, with an overlapping standard deviation.

3.4 Attitude Scales

The scales used have been development with them aim of looking at traits relating to decision delay and inertia, as well as impulsivity in choice making. In pairing the different scales – Need for Closure with Assessment and Impulsivity with Locomotion – we aimed at testing their complimentary assumptions as applied to our decision task, in line with our above-mentioned assumptions around the Somatic Marker hypothesis and the added pressures around uncertainty. Overall, the goal was to link known traits with variations in response times, as expected through task-related pressures and emotional factors. Analysis for these showed that despite the established nature of the scales, the scores did not provide an additional measure to look at individual differences.

Figure 3. Interaction graph; overlaying the trends for recorded response times (blue lines), with the trends recorded for the waveform amplitudes at the different source locations, for each of the three scenario conditions. (A) Trends for S2, located in the parietal lobe, for the early (red line) and late (green line) time intervals. (B) Trends for S1, located in the cingulate cortex, for the early (red line) and late (green line) time intervals. (C) Trends for S4, located in the frontal lobe, for the early (red line) and late (green line) time intervals. The scale for the response times (in ms) was given on the left y-axis, while the scale for both waveform amplitudes sources (in μV) was given on the right y-axis.



4. DISCUSSION

Based on a simplified forced-choice decision-making paradigm it was possible to identify differences in cognitive processing based on consequential variations, following on from propositions based on the decision-making phases. Further, results showed that individuals' responses, when lacking any meaningful information, were affected significantly by the operational environment they were faced with, resulting in redundant deliberation and decision delay.

The analysis showed that the recorded amplitude waveforms at the decision stage of the experiment pointed to a difference in activity between the scenario conditions, proposing cognitive activity relating to deliberation and implementation processes. For the purpose of the discussion, first we focus on the basic visual and cognitive processing at the initial stage where individuals received contextual information about their operational environment. The second part then describes the basic decision-making phases proposed in the 3-stage model, retracing differences in cognitive and behavioural activity and finally, we discuss the extent to which it was possible to link the EEG results with our behavioural measure (reaction time).

4.1 Perception-related components

In the recordings for the first part of the experiment, three sources were identified, which described essentially visual-processing-related potentials. While the sources presented similarities with traditional activation patterns (Coles & Rugg, 1995; Hillyard & Picton, 1987), it was impossible to draw any meaningful conclusions with increased activation as a function of the affective significance of an item (Phelps, 2006; Vuilleumier & Driver, 2007; Padmala & Pessoa, 2008). This was due to the lack of control recordings for the images used, to assess their base activation, as compared to the recordings when used as contextual information for the particular scenarios.

In relation to this, it is important to highlight that the images used for the more consequential scenarios were characterised by more complex visual information. This would be a clear explanation for the stronger activation in those conditions, seeing as no base-line activation was recorded for all three scenario conditions without the contextual information. This did not affect the overall validity of the design, but adds a caveat to any conclusions drawn solely from perception-related components at this stage of the decision-making paradigm.

4.2 Movement-related components & response times

The recordings for the second part of the experiment were aimed at identifying individual decision-related components, as well as the variations in brain activity for each of the scenario conditions, following on from the proposed 3-stage model. The individual's decision was identified with regards to their choice of a wire. Since the focus was on the making of a decision, not which wire, these recordings provided a base-line from which to assess any variations in cognitive as well as behavioural activity.

Implementation Delay

The first source identified at this decision stage was located in the mid-cingulate cortex (S1), which has been related to emotional processing in the brain (Devinski, Morrell, & Vogt, 1995; Paus, 2001; Vogt, 2005). Results here showed larger waveform amplitudes across both time intervals for the low-consequential scenarios. This pointed to a more prolonged activation and stronger emotional engagement for these scenarios, than for the high consequence ones. The mid-cingulate cortex, typically associated with attention (Paus, Petrides, Evans, & Meyer, 1993; Petersen, Fox, Posner, Mintum, & Raichle, 1989), showed in this case that the low-consequence scenarios generated more attentional activity. This finding, perhaps counter intuitively, appears to show that low-consequence scenarios result in stronger and prolonged activation in the cingulate cortex, but when taking into consideration the recordings for response times, a more complex picture emerges.

The response times showed that individuals made significantly quicker decisions in the high consequence conditions (as opposed to low and medium) as soon as they were prompted with the choice of the two wires. These differences were less than 100 ms, showing deviations of around 200 ms, which narrowed the confidence with which clear conclusions can be drawn. Nonetheless, this meant that the recordings for the high-consequence scenarios covered a shorter time-frame when faced with the two wires, before individuals made a movement to commit to their decision. Thus, the heightened activity occurred milliseconds later for the low-consequence conditions; a fact which was masked by the current visualisation, as the overlaid waves gave a skewed picture. This correction showed then, that even if they spent less time on the particular stimuli (i.e. the two wires), activity during this short time still showed a strong increase. A further indication for this was clear from the steep rise for both medium- and high-consequence conditions, just prior to making a decision, and the very similar peaks that all three scenarios reached at that time interval. The same levels of activity were reached for the low-consequence scenarios at the moment when individuals made a choice, but were reached over a longer period of time. During this time individuals observed the two wires and deliberated over which one to choose, reaching the threshold at which time individuals made a choice. This switch was reflected in the parietal lobe (S2), where the movement-related components were taken as indicators of a shift from the deliberation to the implementation stage.

Individuals spent less time deliberating in the high consequence conditions, and reached the same peak level when making a decision. A potential explanation for this relates to the performance pressures placed on the task, as the time-pressure and accuracy-demands were reinforced throughout the experiment. Individuals were quick to move to a resolution in the high-consequence condition, and were already priming themselves for action when given the prompt to select one of the two wires. Thus, the activity in the mid-cingulated cortex (S1) did not reflect the intensity of activity induced by the more emotional conditions, but rather how much time was invested in the deliberation process (MacDonald, Cohen, Stenger, & Carter, 2000; Kuo, Sjöström, Chen, Wang, & Huang, 2009). There was less time expended for the highly consequential scenarios, trying to assess the choices and re-consider the decision plan (strategy), probably because individuals were under higher pressure (i.e. more negative consequence). This would see the longer deliberation for the low-consequence scenarios as a process of re-assessment of their choice within this source area, as they did not feel pressured by the scenario condition or the time constrains. The opposite was observed for the high-consequence scenarios, where the presentation (i.e. visualisation) of the stimuli immediately could have reinforced the emotion and time pressures, thus leading to a faster response, in order to reach a quicker resolution, without prolonged deliberation.

Another factor contributing towards this idea emerged from recordings for the source located in the contralateral parietal lobe (S2), which has been directly linked to activity around planning, preparation and movement (Passingham, 1996; Ball, Schreiber, Feige, Wagner, Lücking, & Kristeva-Feige, 1999). Results here showed that waveform amplitudes for high consequence scenarios were significantly larger than for low-consequence ones. This was observed across two time intervals, pointing to (i) earlier and (ii) more prolonged activation. Thus, individuals in the high-consequence conditions may have moved earlier from a deliberative to an implementative mindset, as shown in an earlier activation of the movement-related areas.

The focus was on movement-related potentials, which have been shown to appear as negative shifts prior to the movement over the primary sensorimotor areas (Kornhuber & Deecke, 1965; Deecke, Scheid, & Kornhuber, 1969; Kristeva, Keller, Deecke, & Kornhuber, 1979). Considering the fast response times for some of the conditions, the emphasis was also on the negative slope (NS’), observed as the steepest part of the negative shift, starting at 500 ms prior to the onset of muscular contraction (Shibasaki et al., 1980). It was clear from the analysis that these potentials were in line with previous models, showing significantly larger amplitudes for the high-consequence scenario within the intervals after the recognised 500 ms for the NS’. This pointed to an earlier onset of the Bereitschaftspotential for the medium- and high-consequence scenarios, resulting also in a more prolonged activity period for these conditions. Thus, individuals were already prepared to make their choice, before they were presented with the two wires.

Furthermore, analysis of the ipsilateral source within the parietal lobe (S3), showed no significant differences between the identified potentials for the three scenario conditions. This was again in line with findings relating to the Bereitschaftspotential, as principally observed over the primary sensorimotor area, contralateral to the movement and over the supplementary motor area (Kornhuber & Deecke, 1965; Neshige, Lüders, & Shibasaki, 1988; Tarkka & Hallett, 1990; Bötzel, Plendl, Paulus, & Scherg, 1993). These observations contrasted with results for the source located in the cingulate cortex. Analysis considering the Bereitschaftspotential pointed towards an early onset of activity, directly relating to the commitment to a choice, identified as the preparation for a voluntary movement. When taking into consideration the response times, results showed that the individuals engaged in decision deliberation earlier (i.e. even before the wires appeared on screen) when faced with high-consequence scenarios. This does not necessarily directly point to the identification of a clear and discrete decision stage, as individuals possibly spent time deliberating about their options - as seen in activity for the cingulate cortex - before even moving on to preparation, planning and commitment to a choice. Nevertheless, these differences pointed to significantly stronger cognitive activity when deliberating about committing to a choice for the scenarios with more critical consequences (i.e. S2). Further, increase in activity for these scenarios (i.e. S1) reached a similar peak as the low-consequence one, over a much shorter period of time. This pointed to an accelerated activation and heightened consideration in terms of emotionally significant factors relating to those scenario conditions.

In order to confirm these propositions, subsequent research should be directed at detailing expectations for the interaction of the deliberation- and implementation-related activity. One possibility would involve presenting both stimuli at the same time, merging the individually-observed stages. Results, following the proposed reasoning, would show even shorter deliberation and a faster switch to implementation for the medium- and high-consequence scenarios, as the urgency is heightened even more, thus pushing individuals to making ever-faster decisions. This would be reflected in even lower and shorter activity in this source area, where the reinforcement of the negative consequences would lead to even greater cognitive ‘blindness’ (i.e. lack of deliberation and re-consideration of choice).

Redundant Deliberation

The aim of this study was to trace the cognitive processing during each decision stage, combining both deliberation and implementation, and to establish whether individuals engaged in redundant deliberation, influenced by contextual task factors. A central feature of the task was that there was no information provided to aid the evaluation of the options. Interestingly, the individuals still spent more time deliberating in one scenario condition than in the other. These observations pointed back to issues around frame- and mind-set shifting (Gollwitzer et al., 1990) even though deliberation between alternatives was futile, since there was no discernible difference between the prescribed choices. Further, the propositions regarding emotional information and the SMH (Damasio, 1994) did not hold up in this particular paradigm, seeing as the low-emotional scenarios resulted in longer deliberating; details of which will be expanded on below. Ideas surrounding possible reasons have been suggested above, but some propositions regarding response suppression and possible set-shifting activity were raised at hand of significant activity in the prefrontal lobe (S4).

One more source, located in the frontal lobe (S4), pointed to the relationship this brain area has with decision-making and problem-solving (Bechara, Damasio, Damasio, & Anderson, 1994; Kringlebach, 2005; Mesulam, 2003; Stuss & Levine, 2002), and more recently with intuitive judgements (Volz, Rübsamen, & von Cramon, 2008). Results showed activation in the high-consequence scenarios, while an active suppression was recorded for the low-consequence ones. These differences did not hold up at the later time intervals closer to the commitment to a choice. Further, the peak amplitudes for all scenario conditions at this source occurred 250 ms after the decision was made, which pointed to an activation relating to the outcome expectation and consequential thinking (Baird & Fugelsang, 2004; den Ouden, Frith, Frith, & Blakemore, 2005), as it was in the time-frame before they received feedback about their decision.

One proposed explanation for the activity, prominently observed in the dorsolateral prefrontal cortex (DLPFC), related to participants' consideration of other solutions and strategies. Especially the right DLPFC has been related to set-frame shifting (Rausch, 1977), while also being responsible for inhibiting one's immediate response (Vanderhasselt, De Raedt, Baeken, Leyman, & D'haenen, 2006). Activation of the same area has been found to enhance the capacity or tendency of individuals to suppress tempting responses (Duncan & Owen, 2000), while it has also been found to curb risk taking (Fecteau, Knoch, Fregni, Sultani, Boggio, & Pascual-Leone, 2007). All of these processes would be directly related to individuals' considerations about which wire to select, inhibiting the immediate response to the alternatives presented. The results showed that activity was significantly stronger for the high-consequence conditions, while recordings for the low-consequence ones showed suppressing activity. This was in direct opposition to conclusions drawn based on the previous sources (S1 & S2), as this pointed to a deliberative engagement with the high-consequence scenario, even though, as pointed out earlier, the activity observed in this area was relatively small in comparison.

Clearly, no direct conclusions were possible based on activity within this source. Research has repeatedly highlighted the difficulty of isolating activity in the prefrontal cortex, due to the complex connectivity with the sensory and motor cortices, as well as the limbic system (Miller & Cohen, 2001). Miller and Cohen's approach describes the 'cognitive control' within the PFC, as applied to any situation where a biasing signal is used to promote task-appropriate responding and regulate corresponding inhibition. Part of this control also pointed to the attention given to the task, differentiating between the voluntary, goal-oriented attentional shift, and involuntary, stimulus-dependent shift (Sohn, Ursu, Anderson, Stenger, & Carter, 2000). In this case, expecting a goal-oriented shift, as the type of information is still delivered through stimuli with similar characteristics, but the focus changes from prioritising accuracy to prioritising speed.

Based on this particular sub-region, acknowledging the complexity of the PFC, none of the propositions accurately described the activity observed during the current decision paradigm. Nonetheless, the results provided some grounds on which to expand on particular substrates of the activity, in order to isolate its relationship with the particular decision-making task and the key characteristics influencing the problem-solving processes. A more specific experiment, focusing on specific performance goals, would allow for a more confident identification. But it is important to highlight, that the DLPFC has been identified as playing a key role when solving ill-structured problem tasks (Gilbert, Zamenopoulos, Alexiou, & Johnson, 2010), as well as being key for integrating events over time (Fuster, 2001) and being essential in the timing of duration (Jones, Rosenkranz, Rothwell, & Jahanshahi, 2004); all of which are processes expected to feature prominently within this particular decision-making paradigm.

4.3 Emotions

When considering how the emotional variations – lower or higher consequence – were reflected in the cognitive processing during the decision making process, a number of congruent observations emerged between this study and the available literature.

Analysis showed that the high-consequence conditions had an effect on a number of processes identified in various sources, which links directly to proposals from the area of affective neuroscience, about a number of mental operations and specific neural substrates directly linked to the perception of emotional information (Davidson & Sutton, 1995). In terms of value placed on each scenario condition and the consequential information, findings were in line with propositions based on an emotional-motivational system (Lang, Bradley, & Cuthbert, 1990; 1992), pitting approach-activating and aversion-activating conditions against each other, as a continuation from traditional conditioning literature (Konoroski, 1976). Furthermore, variations in cognitive load (*i.e.* problems with greater difficulty, engagement or distraction) have been correlated with larger waveform amplitudes in EEG (recordings) for cognitive indices (Stevens, Galloway, & Berka, 2007). This was replicated in this study, where the high-consequence scenario resulted in greater cognitive loading.

More directly relating to source localisation, especially the frontal lobe (S4), findings here replicated previous research, which showed greater right frontal activity during negative emotion images (Davidson, Ekman, Saron, Senulis, & Friesen, 1990). Further, in line with findings showing frontal activity to reflect approach-withdrawal motivation (Harmon-Jones, 2003), expectations of more activity for those scenarios that would like to be avoided by individuals were again fulfilled within this research.

Overall, the advances in neuroanatomical frameworks have continued to provide physiological evidence for the ideas of interoceptive states (Damasio, 1994; Craig, 2008). Based on these particular results, clear observations emerged around the effect emotional variations can have on cognitive decision-making processes. While results for response times showed a heightened urgency for the medium- and high-consequence scenarios, more in-depth observations into cognitive activity also pointed to earlier and more prolonged deliberation for these conditions. The main difference seemed to emerge when individuals were faced with the actual choice they had to make, resulting in an increase in cognitive activity over a short period of time, in which the threshold to make a decision was reached early quicker for the more emotional scenarios. In the simplest of terms, using emotions to anticipate feelings in order to "*control our behaviour towards a maximisation of positive emotions and a minimisation of negative ones*" (Hardy-Vallée, 2007; p. 945), individuals were driven by the desire to resolve the problem quicker in some of the more emotional scenario conditions.

Results showed that the priming in both parts of the experiment, visual perception and decision prompt, contributed to a heightened level of preparedness for the more consequential scenarios. This was highlighted by the recordings for the visual response and movement readiness, leading to an accelerated response in the more consequential scenarios (Pessoa, 2008). Individuals were more pre-occupied with making speedy decisions, rather than correct ones, as they were possibly overwhelmed by the scenario and felt the task was not solvable based on their strategies. On the other hand, they spent a slightly longer time deliberating about their choice in the low-consequential scenarios. One possibility might have related, as already pointed out above, to the perceived solvability of the task and the shifting performance pressure from speed to accuracy.

In combination, considering the results for both stages within the experiment, the observations gathered provide further contribution to the understanding of the effect situational and emotional factors have on fundamental decision-making processing. In both cases, the results further contributed to the task of identifying these experimentally, combining previous research around the effect of emotions on cognitive processing (Oatley et al., 2006) and their effect on decision making (Loewenstein & Lerner, 2003).

5. CONCLUSION

Following on from established ideas around the effect of emotions on cognitive processing, results here allowed the identification of isolated activity, which was to some extent affected by these manipulations. From the basic task of recognising operational settings (evaluation), to the more complex processes relating to deliberation and implementation of a choice, results in this study showed that emotions had a significant relationship with and influence on brain activity, in terms of amplitude as well as duration. While higher consequence scenarios resulted in stronger and prolonged activation, behavioural responses did not show a reflection of this activity in the form of delay in making a decision, and indeed the opposite was found when compared to the other conditions.

The study also confirmed that, even in the absence of information on which to base a decision choice, individuals engaged in deliberative processes. Still, the study provided a clear identification of the different variations for the particular task, providing a basis for further more complex manipulations, in order to recognise stronger affecting factors in similar operational environments. Subsequent studies are aimed at identifying the factors influencing the differing deliberation processes, before moving on to the interaction these have with decision delay.

Chapter III

Feedback Influence

Experiment 2

1. INTRODUCTION

In Experiment 1 (see *Chapter II*), results pointed to differences in brain activity during the deliberation phase, before moving to the implementation of a decision. Individuals had time to think about what choice to make, before being prompted to commit to one. This activity was expected to be stronger for the more emotional conditions, as these conditions amplified concern and anxiety experienced through the expectation of a more negative consequence, which in turn raised participants' readiness to quickly make a decision. Conversely, less deliberation and implementation activity was expected for the non-emotional conditions, as individuals were less concerned and pressured by the outcome.

Contrary to expectations, individuals showed less deliberation activity during the more consequential task conditions, than during the low-consequence ones; while implementation activity was still stronger and more prolonged during the emotional conditions. This was interpreted as individuals engaging in longer deliberative processes for the low-consequence scenario conditions, while they moved quicker to an implementation stage for the emotional ones. Explanations in the experiment's discussion pointed to the overlap of recordings, with the overlaying of brain activity on top of the reaction times showing a more dynamic picture of activity.

One explanation for this difference between the various scenario conditions related to the individual's commitment to the task and focus on certain performance pressures. Observations pointed to individuals giving up on solving the task, due to the perceived insolvability of the decision paradigm, as they rather focused on making quick decisions, to reach a faster resolution. This occurred considerably more for the more consequential scenarios, due to the negative consequences of these scenarios. This shift in effort and engagement was strongly influenced by the design of the decision problem and the instructions provided, aimed at increasing the performance pressures. Individuals simply lost confidence about being able to make the correct choice (accuracy), leading them to just focus on making choices quickly (speed).

Once accounting for this shift, the most surprising observation related to the activity leading up to the decisions in the non-emotional scenario conditions. Individuals engaged in deliberative processes, even in situations where there was no information available upon which to base judgement and preferential choice. The goal at this stage was to identify the reason for the differences observed between the scenario conditions. It was possible that the difference was related to individuals' perception of solvability and active engagement with the decision task, as influenced by the feedback they received (Henson, Rugg, Shallice, & Dolan, 2000).

Following on from the same decision-paradigm, participants' perceived accuracy was manipulated during the task. The idea was that, by presenting individuals with more or less positive/negative feedback on their choices, it was possible to influence how strongly they engaged with the task, as they gained a better idea about the solvability of the problem. These propositions followed on from findings around the effect of mood described in other decision tasks (de Vries, Holland, & Witteman, 2008), as a significant influence on performance. Similarly, especially when combining the pressures of making decisions in high-risk scenarios and the repeated failure to make the correct choice, the notion of heightened anticipated regret (Zeelenberg, van Dijk, Manstead, & van der Pligt, 2000) come to the forefront and is expected to possibly affect the task performance.

All of these variations were aimed at engaging the individual more with the task, raising or lowering the level of (perceived) solvability. The prediction was that this engagement would result in extended deliberation with the task, providing a longer window of observable activity, showing significant differences for emotional scenarios, due to the added complexity and negative outcome. This experiment focused on reaction times (behavioural) and a qualitative insight, expanding on ideas around confidence, and the effect of positive and negative reinforcement, as provided through feedback.

1.1 Objectives and Hypotheses

The goal was to further identify the factors influencing performance in the decision paradigm, in order to answer the questions raised in Experiment 1. A slightly amended version of the decision paradigm was used, focusing on varying the number of correct and incorrect responses participants made. This was done in order to assess the effect feedback and the perceived confidence in their ability to solve the task had on their performance on the task, based on behavioural and self-reflective measures. The following objectives were also considered:

> Guided by their overwhelming positive or negative feedback, participants in such groups will produce faster response times.

> Participants receiving a similar number of positive and negative feedback to their choices, will produce longer response times.

2. METHOD

2.1 Participants

Fifteen individuals (12 females, 3 males) participated in this study. They ranged in ages from 18 to 39 years, with a mean age of 21 years, and were drawn from a sample of students at the University of Liverpool. Participants were split into three equal groups, consisting of 5 individuals each. Each group was assigned a level of low, medium and high feedback, based on the experimental conditions they completed.

2.2 Procedure

Participants were seated in a comfortable chair, inside a dim-lit room, and were left alone to complete the experiment. All task-related information was presented to them on a computer screen, and they used a mouse placed below their hand to give their responses.

The experiment consisted of a series of decision situations, at the end of each individuals were asked to make a choice between two random alternatives under time pressure. The task consisted of a 'bomb scenario', where participants were asked to imagine themselves operating in the various environments pictured and where the objective was to 'cut' a wire and disarm a bomb. Following this, they faced a decision stage and had to choose between two alternatives, in the form of two different-coloured wires (see *Table 1*) (failing to cut one of the wires sufficiently quickly led to automatic 'detonation'). The basic premise of the decision problem focused on a binary negative outcome paradigm, where participants had to choose between two arbitrary alternatives, not knowing which would be the correct wire - reinforced through time constrains and performance pressures - and where a 'wrong' decision lead to a negative outcome.

First, they were presented with a context-setting scenario involving either:

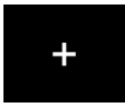
(i) a light-bulb, which they had to switch off by picking a wire (low consequence condition),
(ii) an industrial courtyard, in which the wires were used to disarm a bomb (medium consequence condition), or
(iii) children on a playground, in which the wires were used to disarm a bomb (high consequence condition).

In summary then, the stimulus indicated one of three conditions: 1) low consequence, 2) medium consequence, and 3) high consequence. This was followed by an image of a light switch (low consequence condition) or explosive device (medium- and high-consequence conditions), to reinforce the situational context. Finally participants were prompted to choose between a red or blue wire 'connected' to the particular device. Failure to make a decision or making a wrong one, led to detonation of the device. Following each choice, they received feedback in the form of a "*CORRECT*" or "*INCORRECT*" on-screen message.

The instructions, prior and during the experiment, all emphasised the need to take quick and decisive action. Participants were told that they would be assessed on their accuracy as well as their speed, forming part of an overall learning task. What participants did not know, was that the order and number of correct or incorrect decisions was set prior to the experiment, and they had no influence on the decision task. This was done in order to assess, if in the absence of any information and clear solution, participants still deliberated about their decision. Despite having no control and no clear pattern in the results, the most rational suggestion would lead to just cutting any wire, as there is no preferential value assigned to either.

A total of 60 stimuli series were presented in three blocks. At the end of each block, participants were presented with a brief 8-item questionnaire to assess their experience so far. The three experiment groups differed in the type of feedback they received, between the low, medium or high conditions. This related to the percentage of positive or negative feedback they received about their decisions, separated respectively into 20%, 50% or 80% positive.

Table 1. Decision Paradigm

STAGE	Evaluation		Deliberation	Choice	
STIMULI	Mask	Context	Device	Decision	Feedback
			 		CORRECT or INCORRECT or TOO SLOW
TIME	*2,000ms*	*2,000ms*	*2,000ms*	*3,000ms*	*1,500ms*

The decision scenarios were designed using Inquisit (Millisecond Software v3.0.4, Seattle – USA), and recordings for each participant's response times were taken at each decision stage.

2.3 Measures

The main measure for this experiment described the time (in milliseconds) it took participants to make a decision, once they were presented with the available alternatives. Further, they completed an 8-items questionnaire (see *Appendix B*) after each of the three blocks, where they responded to questions about their attitudes towards and experience of the experiment using a 10-point Likert scale. At the end of the experiment they completed a brief questionnaire (*see Appendix C*), which provided a qualitative description of their decision-making process and an overall perspective of the experience during the task.

2.4 Analysis

The effect of feedback on response time was assessed using an analysis of variance (ANOVA), where the recordings between the groups were compared for each of the scenario conditions. The independent variables for the analysis were the three different scenarios (low-, medium- and high-consequence), differentiating between the three feedback groups (low, medium and high). Pair-wise comparisons were carried out between the three scenarios, and a 95% confidence level was used throughout. Similar comparisons were carried out between the three different blocks

(Block A, Block B & Block C), to look at possible changes over time, and between the feedback groups, to look at the effectiveness of the manipulations. In addition to this, qualitative data was gathered from participants' post-task questionnaires, to gain an insight into strategies and thought processes during the experiment.

3. RESULTS

The results will detail the analysis of the experiment in three parts, with a fourth one providing some qualitative description based on the post-task questionnaire. First, the focus will be on assessing any possible repetition effect across the blocks of the experiment. Afterwards, the analysis will look at indicators for the effect the manipulations had on participants' behavioural and attitudinal responses. Lastly, the analysis will compare the reaction times for the different feedback conditions and see how they reflected changes for the specific consequence scenario conditions.

3.1 Repetition

Results for the repeated measures ANOVA for the response times showed that there were some differences between the blocks in two of the consequence scenarios. On the other hand, repeated measures ANOVAs were also carried out for the various scale items completed between the different phases. These showed that there were no significant differences between the ratings given by the participants at the different points in time during the decision task.

Considering that the sphericity assumptions were violated for the response times in some of the scenarios conditions (low- and medium-consequence), the large standard deviations recorded and the small samples sizes available for the attitude scales, the results showed an overall homogeneous distribution of response times and ratings over the three blocks. Despite some significant differences in some of the feedback conditions, it was still safe to say that overall there was no significant change in response times or scale ratings over time. This allowed for the collapsing of the three blocks and a more in-depth analysis of the response times for the different scenarios conditions across all three feedback groups.

3.2 Feedback Manipulation

Before looking at the comparative analysis, it was important to assess the effectiveness of the feedback manipulations and the participants' groupings. For this, response times and scale ratings were compared between the three feedback groups.

Results for all three individual blocks (i.e. A, B & C) showed that there were no significant differences between the response times for each consequence condition (i.e. low, medium & high) when comparing them within the different feedback groups (i.e. low, medium & high). Further, taking into consideration the non-significant findings for the three different blocks, the same analysis was carried out with all of them collapsed together (see *Table 3*).

Table 2. Mean (SD) response times for each feedback group in all three consequence conditions

Consequence Scenario	*Feedback Group*		
	Low	Medium	High
Low	926.35 (725.29)	914.02 (669.03)	796.76 (516.83)
Medium	772.07 (521.04)	900.76 (596.62)	680.64 (377.14)
High	773.30 (587.97)	851.82 (559.11)	674.3 (319.55)

The analysis showed that there were no significant differences between the response times for each individual consequence condition when compared between the different feedback groups.

For the scale ratings, analysis was carried out again on the blocks collapsed together, based on the findings above. Results here showed that there was a significant difference between most of the scale ratings, with exception of three of the items (see *Table 4*). Due to the distribution of the recorded data, a non-parametric Kruskal-Wallis ANOVA was carried out.

Table 3. Median scale ratings across all three feedback groups

Scale Item	*Feedback Group*			Analysis	
	Low	Medium	High	*H* (2)	*p*
% Correct	*10*	*30*	*70*	*32.103*	*.000 **
Concentrate	*7*	*6*	*8*	*6.479*	*.035 **
Solved	*2*	*3*	*7*	*17.103*	*.000 **
Strategy Rev.	6	5	7	2.312	.329

Stressed	*8*	*5*	*4*	*13.204*	*.000 **
Anxious	*7*	*7*	*4*	*10.156*	*.004 **
Quickly	7	6	8	4.2	.124
Accurately	8	7	7	0.839	.657

** Significant difference between the feedback groups, at p < .05.*

Mann-Whitney tests were carried out to follow up on the significant findings, to identify where the differences were. A Bonferroni correction was applied and so all effects are reported at a .0167 level of significance. When asked about how many trials individuals thought they had answered correctly, there was a clear trend, with an increase from the low- to medium-feedback groups (U = 41, r = -0.56), and from the medium to high-feedback one (U = 10.5, r = -0.78). It appeared that individuals in the low-feedback group rated their concentration level higher than those in the medium-feedback one (U = 54.5, r = -0.45). On the other hand, results showed that individuals in the high-feedback group claimed to have solved the task when compared to those in the medium- (U = 21.5, r = -0.7) and low-feedback (U = 33.5, r = -0.6) groups. When it came to their experience of the task, individuals rated their stress level for the low-feedback condition higher than for the high-feedback one (U = 24, r = -0.65). Similarly, individuals in the low-feedback group also rated their anxiety significantly higher than those in the high-feedback one (U = 56.5, r = -0.43).

The results showed no uniform reflection of the feedback manipulation having a significant effect on the individual measures, for both the response times as well as the rating scales. Despite some individual scale items showing a significant change when considering the groupings, these did not follow a consistent trend throughout the task. Further, weaknesses relating to the small samples sizes and the distribution of the data, pointed to small or medium effect sizes in terms of variation accounted for.

3.3 Response Times

Despite no clear confirmation of the feedback manipulation's effectiveness when looking at the behavioural and attitudinal measures, comparative analyses were carried out between the response times for the different scenarios in each individual feedback group.

Results showed that there was no difference between the response times for the scenario conditions when looking at the individual low and medium feedback groups (see *Table 5*).

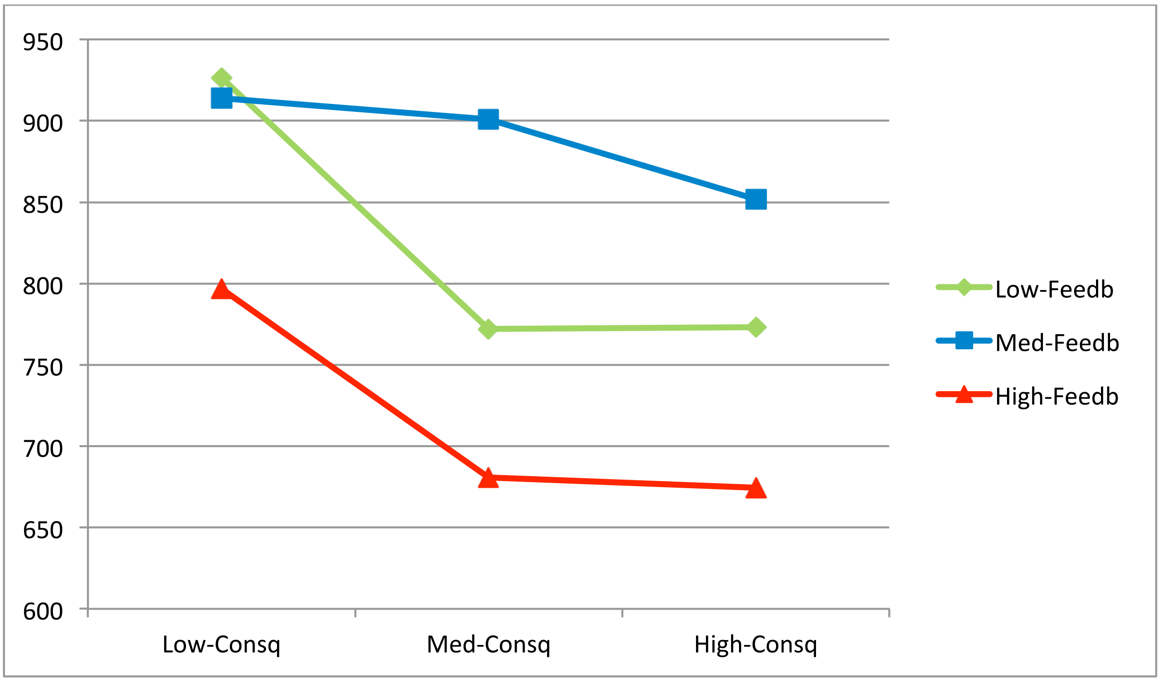
Table 4. Mean (SD) response times for each consequence scenario in all three feedback groups

Feedback Group	*Consequence Scenario*			Analysis	
	Low	Medium	High	*F* (2, 178)	*p*
Low	926.35 (725.29)	772.07 (521.04)	773.3 (587.97)	2.576	.079
Medium	914.02 (669.03)	900.76 (596.62)	851.82 (559.12)	0.404	.668
High	796.76 (516.83)	680.64 (377.14)	674.3 (319.55)	3.422	.035*

** Significant difference between the consequence conditions, at p < .05.*

On the other hand, there was a significant difference between the scenarios for the high feedback group, F (2, 178), = 3.422, p = .035. Analysis showed that response times for the low-consequence scenarios were significantly slower than for the medium-, F (1, 89) = 4.527, p = .036, and high-consequence ones, F (1, 89) = 4.656, p = .034 (see *Figure 1*).

Figure 1. Mean response times for the three separate feedback groups in each individual consequence scenario



Considering the comparisons for the response times between the feedback conditions did not show any significant differences and the scale ratings did not show uniform differences across the groups, a further analysis was carried out between the scenario conditions without accounting for the feedback grouping. Results showed that there was a significant difference between the consequence conditions, F (2, 530) = 4.624, p = .010. Comparisons showed that response times for the low-consequence scenarios (M = 878.33, SD = 642.03) were significantly slower than those for the medium-consequence (M = 784.68, SD = 512.54), F (1, 265) = 5.238, p = .023, and high-consequence (M = 766.37, SD = 505.51), F (1, 265) = 7.375, p = .007, ones.

Response times for the high-consequence scenarios were still shorter than for the non-consequence ones, where feedback variations was not a contributing factor to variation between the groups.

3.4 Task Questionnaire

After completing the decision paradigm, participants filled out a post-task questionnaire. These responses provide a qualitative insight into the decision-making processes and individuals' experience during the experiment, complementary to the behavioural measures.

When individuals were asked about particular strategy applied to solve the task (Q.2), there was some variation amongst the responses, reflecting a post-experiment rationalising of their performance. Some in the low-feedback group stated they did not try any strategy, while others described some early attempts. All individuals applied some strategy in the medium-feedback group, even if some failed as the task progressed ("*That didn't work [...] I just went with my gutfeeling* (sic)."). Similarly, all those in the high-feedback tried out a strategy, with some giving extended commentary and description of the process ("*If a bomb =cut blue wire for people, cut red wire for buildings without people. If a switch, cut red wire for light, cut blue wire for sound.*").

When asked if they reconsidered their choices at the very last moment (Q.4), individuals in the low-feedback group stated that they did not and simply guessed, as they had not settled on a successful strategy ("*I ended up just guessing as I could not* *figure out any form of strategy.*"). Those in the medium-feedback group stated that they were insecure about their own strategy while they did not reconsider their choices ("*I was doubting myself due to other answer being wrong.*"), while those in the high-feedback group did not stop to reconsider, especially following negative feedback from previous choices ("*Occasionally, because although my strategy worked most of the time, sometimes the blue/red wire would be incorrect.*").

In terms of the time available and individuals' focus on speed or accuracy, there was a general consensus across all three feedback groups. As reflected in the response times and the consistent scoring below the 3 seconds time-limit, all individuals made their decision within the given time frame. This was further reflected in their answers (Q.5 & Q.6), where they stated that accuracy was their main concern while completing the task and that more time would not have aided them in developing a more successful strategy.

When asked about the solvability of the task, and how difficult they found it (Q.7), there was again a variation in the answers given by the three feedback groups. Those in the low-feedback group stated that it was not solvable, as they failed to gain meaningful information from their own performance, and thus resigned to guessing ("*I was consciously looking for clues and feedback, but I did not find any and so my decisions were pretty random.*"). Those in the medium-feedback group were unsure about the solvability or perceived difficulty of the task, reflecting on their own performance ("*I can't say it was or wasn't too hard, because I'm not quite sure if my method of solving the task was good.*"). Finally, those in the high-feedback group stated that the task was solvable, even if they admitted getting some of the decisions wrong. They highlighted that some of the decision scenarios seemed clearer than others, while others simply required more effort ("*... I thought it was solvable as although some seemed straight forward others were more difficult...* ").

When asked about the correct solution (Q.8), most in the low-feedback group stated that they were unable to figure out the correct solution, with others stating that there was no right solution ("*I got so many wrong that I thought [...] that in fact it was predetermined answers.*"). All individuals in the medium-feedback group stated that they had no idea what the solution was, while those in the high-feedback one suggested some theories about the task's solution and some described complex strategies ("*I looked at the colour in the pictures and tried to memorise each answer.*").

4. DISCUSSION

Aimed at identifying potential factors which affected performance in the forced-choice decision paradigm, the experiment looked at the possible effect perceptions of feedback for each consequence scenario have on performance. Focused on behavioural responses, the analysis looked in detail at the various phases of the experiment, before assessing the effect it had on the overall validity of the design.

While some differences were highlighted in terms of the repetition of the task and any possible issues relating to habituation, these were not consistent across the feedback and consequence conditions. There was an overall homogenous distribution of the scores between the different phases, with no significant variation over time, pointing to a consistent and prolonged engagement by the participants, as further reflected by the absence of change in their ratings.

The manipulations did have a clear effect on participants' scale ratings, showing that those in the high-feedback condition indeed felt they had found the solution to the task. In contrast, those in the low- and medium-feedback groups stated feeling more stressed and anxious about the task, while they more often described frustration and re-assessment of their choices. The differences were present only in some of the ratings and no variation was observed when asked about their need to be accurate or quick in their decisions. Nonetheless, the manipulations did still reflect some expectations about the effect feedback would have on individuals' ratings and task-descriptions.

When looking at the effect the feedback manipulations had on response times in each of the consequence scenarios, the results showed that they did not significantly affect individuals' performance. Despite showing that the feedback did affect their perception of accuracy and their performance during the decision task, it did not affect the speed with which they made their decisions. This provided the first indication that despite propositions about the possible effect feedback could have on decision-making, findings in this particular experimental setting pointed to an unchanged performance, despite the different positive or negative reinforcements.

It was then important to assess if these variations, even if not observed within the individual consequence scenarios, did have an influence when compared between them. Findings showed that response times were significantly different only in the high-feedback group, with individuals responding significantly slower in the low-consequence scenarios than in the medium- and high-feedback ones. Overall, those in the group receiving mostly positive feedback showed faster response times, possibly driven by their elevated confidence in their performance (Loewenstein, Weber, Hsee, & Welch, 2001; Bagozzi, Dholakia, & Basuroy, 2003). But these differences did not follow similar propositions when considering the low- and medium-feedback groups, thus putting in question the overall effect it had on this particular decision paradigm. Further, considering the lack of significant variations in the individual feedback groups, a comparison between the scenarios for all groups collapsed together showed again that the low-consequence scenario resulted in a faster response for the medium- and high-consequence ones. This replicated the overall findings from Experiment 1, where individuals were guided by the environment rather than the feedback, when there was no meaningful information available.

On the various behavioural and self-reflective measure collated, it was clear that feedback did not have an effect on the time it took individuals to make a choice in this particular decision environment. In other words, while their feedback condition was reflected in their self-reported ratings and task-description, it did not influence their overall performance. Against expectations, these variations did not drive them in any particular way to make significantly faster or slower decisions in the forced-choice scenario they were presented with.

This has important implications for the experiment design, as it clarifies any issues that could relate to the effect feedback had on the task and especially on the observed variation observed for the different consequence scenarios. At the same time, the medium-feedback condition, which is equal to the one used in Experiment 1 and the subsequent ones, did not show any significant difference between the groups, which made it possible to rule these out as affecting factors. Moreover, the experiment clearly engaged individuals and maintained performance-pressures across the task, and it did also provided clear observations to further explore the individual cognitive processes and how these affect the behavioural responses.

5. CONCLUSION

Addressing questions raised in Experiment 1, this particular experiment looked at the potential effect varying degrees of positive or negative feedback could have on individuals' performance. Findings showed that this was not a significant factor in the current decision paradigm and the behavioural response to the task. While variations in the feedback showed to influence perceptions about individuals' performance, they did not affect the time it took them to make a choice under the different scenario-consequence conditions. Moreover, as results pointed to a similar variation in response times as observed in Experiment 1, with responses for the low-consequence scenarios still being faster than the other two, these findings again confirmed the role the different operational conditions seem to play in forced-choice decision environments when lacking any meaningful information.

Chapter IV

Information Load

Experiment 3

1. INTRODUCTION

When considering behavioural responses to the decision paradigm in Experiment 1 (see *Chapter II*), results showed that individuals responded significantly faster in the low-consequence scenarios than in the other two. But when taking into consideration the cognitive measures recorded during the task, results showed heightened and prolonged brain activation during the more consequential scenarios. This pointed to a fundamental difference in engagement and processing in the brain regions corresponding to problem-solving and movement preparation.

The question raised following this focused on the linear set-up of information and stimuli presentation in the current experimental design, which resulted in an overlap of cognitive processing and behavioural response. Due to the repetitive nature of the experiment, participants developed an expectation and were able to anticipate the next decision-making point, leading to an anticipated evaluation as well as deliberation. It was this earlier activation, as reflected in the underlying brain activity recorded, that resulted in a significant difference between the consequence scenarios.

One proposition regarding this focused on the idea of cognitive loading, looking into the amount of information that is processed at any given time (Sweller, 1988; Sweller, Ayres, & Kalyuga, 2011). Within the framework of this decision-making paradigm, this referred to the presentation of the contextual information, in the form of the operational scenario, and the presentation of the two available alternatives. All of this played out in a sequential manner, with sufficient time between each new piece of information. In order to identify what effect this linear processing had on the behavioural response, it was necessary to assess how the simultaneous presentation of all available information would affect attention, deliberation and implementation within the decision-making process.

Additionally, propositions around the effect of feedback manipulations, in the form of varying levels of positive or negative feedback to individuals' choices, were incorporated again in this experiment. Carrying on ideas around the effect of mood on decision tasks (de Vries, Holland, & Witteman, 2008), and a heightened feeling of anticipated regret (Zeelenberg, van Dijk, Manstead, & van der Pligt, 2000), these were expected to significantly affect performance during the task.

1.1 Objectives and Hypotheses

The goal of the experiment was to identify how cognitive loading influences performance in this forced-choice decision paradigm, in order to clarify the proposition made in Experiment 1. Using a slightly amended version of the decision paradigm, the focus was on the simultaneous presentation of scenario and decision information, while still combining this with the varying degrees of feedback manipulations identified in Experiment 2 (see *Chapter III*). The aim was to assess what behavioural effect, if any, this more complex presentation of information had on performance in this particular decision paradigm, influencing both deliberation and implementation phases within the decision-making process. The following objectives were considered:

> When participants are presented with all task-related information simultaneously, the higher-consequence scenarios will result in longer response times, as the deliberation and implementation processes are compressed and need to compete with the initial processing of the contextual details.

- When operating in a setting of mostly positive or negative feedback, participants in those individual feedback groups will result in faster response times, as influenced by their performance mood. Similarly, individuals operating in a setting which results in the same amount of correct as well as incorrect decisions will take longer to make their decisions, as affected by the heightened uncertainty about the effectiveness of their solution strategy and regular re-assessment.

2. METHOD

2.1 Participants

Fifteen individuals (12 females, 3 males) participated in this study. They ranged in ages from 18 to 40 years, with a mean age of 21 years, and were drawn from a sample of students at the University of Liverpool. Participants were split into three equal groups, consisting of 5 individuals each. Each group was assigned a level of low, medium and high positive feedback, based on the experimental conditions they completed.

2.2 Procedure

Participants were seated in a comfortable chair, inside a dim-lit room, and were left alone to complete the experiment. All task-related information was presented to them on a computer screen, and they used a mouse placed below their hand to give their responses. The task consisted of a 'bomb scenario', where participants were asked to imagine themselves operating in the various environments pictured and where the objective was to 'cut' a wire and disarm a bomb. They faced a decision and had to choose between two alternatives, in the form of two different-coloured wires (see *Table 1*) (failing to cut one of the wires sufficiently quickly led to automatic 'detonation'). The basic premise of the decision problem focused on a binary negative outcome paradigm, where participants had to choose between two arbitrary alternatives, not knowing which would be the correct wire - reinforced through time constrains and performance pressures - and where a 'wrong' decision lead to a negative outcome.

The pictured environments involved either:

(i) a light-bulb, which they had to switch off by picking a wire (low consequence condition),

(ii) an industrial courtyard, in which the wires were used to disarm a bomb (medium consequence condition), or

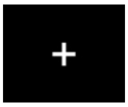
(iii) children on a playground, in which the wires were used to disarm a bomb (high consequence condition).

This was accompanied by an image of a light switch (low consequence condition) or explosive device (medium- and high-consequence conditions), to reinforce the situational context. Participants were then prompted to choose between a red or blue wire ‘connected’ to the particular device. Failure to make a decision or making a wrong one, led to detonation of the device. Following each choice, they received feedback in the form of a “*CORRECT*” or “*INCORRECT*” on-screen message.

The instructions, prior and during the experiment, all emphasised the need to take quick and decisive action. Participants were told that they would be assessed on their accuracy as well as their speed, forming part of an overall learning task. What participants did not know, was that the order and number of correct or incorrect decisions was set prior to the experiment, and they had no influence on the decision task. This was done in order to assess, if in the absence of any information and clear solution, participants still deliberated about their decision. Despite having no control and no clear pattern in the results, the most rational suggestion would lead to just cutting any wire, as there is no preferential value assigned to either.

A total of 60 stimuli series were presented in three blocks. At the end of each block, participants were presented with a brief 8-item questionnaire to assess their experience so far. The three experiment groups differed in the type of feedback they received, between the low, medium or high positive feedback conditions. This related to the percentage of positive or negative feedback they received about their decisions, separated respectively into 20%, 50% or 80% positive.

Table 1. Decision Paradigm

STAGE			SCENARIOS		
STIMULI	Mask	Low-Consequence	Med-Consequence	High-Consequence	Feedback
					CORRECT or INCORRECT or TOO SLOW
TIME	*2,000 ms*	*5,000 ms*	*5,000 ms*	*5,000 ms*	*3,000 ms*

The decision scenarios were designed using Inquisit (Millisecond Software v3.0.4, Seattle – USA), and recordings for each participant's response times were taken at each decision stage.

2.3 Measures

The main measure for this experiment described the time (in milliseconds) it took participants to make a decision, once they were presented with the available alternatives. Further, they completed an 8-items questionnaire (see *Appendix B*) after each of the three blocks, where they responded to questions about their attitudes towards and experience of the experiment using a 10-point Likert scale. At the end of the experiment they completed a brief questionnaire (see *Appendix C*), which provided a qualitative description of their decision-making process and an overall perspective of the experience during the task.

2.4 Analysis

The effect of feedback on response time was assessed using an analysis of variance (ANOVA), where the recordings between the groups were compared for each of the scenario conditions. The independent variables for the analysis were the three different scenarios (low-, medium- and high-consequence), differentiating between the three feedback groups (low, medium and high). Pair-wise comparisons were carried out between the three scenarios, and a 95% confidence level was used throughout. Similar comparisons were carried out between the three different blocks, to look at possible changes over time, and between the feedback groups, to look at the effectiveness of the manipulations. In addition to this, qualitative data was gathered from participants' post-task questionnaires, to gain an insight into strategies and thought processes during the experiment.

3. RESULTS

The results will detail the analysis of the experiment in three parts, with a fourth one providing some qualitative description based on the post-task questionnaire. First, the focus will be on assessing any possible repetition effect across the blocks of the experiment. Afterwards, the analysis will look at indicators for the effect the manipulations had on participants' behavioural and attitudinal responses. Lastly, the analysis will compare the reaction times for the different feedback conditions and see how they reflected changes for the specific consequence scenario conditions.

3.1 Repetition

Results for the repeated measures ANOVA for the response times showed that there were some significant differences within the various blocks (see *Table 2*). They were associated with statistically significant differences in response times for the low-consequence scenarios within the high-feedback group, $F\ (2, 58) = 17.032$, $p = .000$, with post-hoc showing that recordings for the first block resulted in slower response times than the second block, $F\ (1, 29) = 21.357$, $p = .000$, and the third block, $F\ (1, 29) = 17.135$, $p = .000$.

Table 2. Mean (SD) response times with significant differences between three blocks of the decision task, for all consequence scenarios in each feedback group

Feedback Group	*Consequence Scenario*	*Block*			*Analysis*	
		A – First	B – Second	C – Third	*F (2, 58)*	*p*
High	Low	2023.33 (1182.3)	1140.43 (537.97)	1032.40 (572.91)	17.032	.000*
	High	1594.03 (1039.8)	1372.70 (776)	1029.57 (481.56)	6.730	.002*

** Significant difference between the blocks, at p < .05.*

Response time for the high-consequence scenarios also showed a significant difference between the blocks within the high-feedback group, $F\ (2, 58) = 6.730$, $p = .002$, with the third block resulting in significantly faster responses than the first block, $F\ (1, 29) = 11.988$, $p = .002$, and the second block, $F\ (1, 29) = 6.871$, $p = .014$.

Finally, repeated measures ANOVAs were carried out for the various scale items completed after each of the blocks. These showed that there were significant differences only for the concentration ratings in the high feedback conditions, F (2, 8) = 5.032, p = .038, with the level of concentration being rated significantly lower for the second block (M = 6.8, SD = 0.45) than for the first one (M = 7.8, SD = 0.84), F (1, 4) = 10, p = .034. There were no other significant differences between the ratings given by the participants at the different points in time.

Despite some significant differences in the analysis, as well as the large standard deviations recorded and the small samples sizes represented in the attitude scales, the results showed an overall homogeneous distribution of response times and ratings over the three phases. It was still safe to support the view that there was no significant change in response times or scale ratings over time. This allowed for the collapsing of the three phases and a more in-depth analysis of the response times for the different scenarios conditions across all three feedback groups.

3.2 Feedback Manipulation

Before moving on to the comparative analysis, it was important to assess the effectiveness of the feedback manipulations and the participants' groupings. For this, response times and scale ratings were compared between the three feedback groups.

Results for the individual blocks (i.e. A, B & C) showed that there were significant differences between the response times for some of the consequence scenarios (i.e. low, medium & high) when comparing them within the different feedback groups (i.e. low, medium & high) (see *Table 3*).

Table 3. Mean (SD) response times for each feedback group in all consequence conditions, during each of the three blocks

Block	*Consequence Scenario*	*Feedback Group*			*Analysis*	
		Low	Medium	High	*F (2, 104)*	*p*
A	Low	1990.94 (879.89)	1842.91 (786.23)	1920.51 (1135.7)	0.215	.807
	Med	2015.91 (942.09)	1676.86 (887.96)	1472.54 (912.83)	3.152	.047 *
	High	1658.33 (736.14)	1680.67 (849.1)	1594.03 (1039.8)	0.078	.925
B	Low	1702.3 (967.72)	1707.3 (946.16)	1140.43 (537.97)	4.481	.014 *
	Med	1602.6 (1032.14)	1957.89 (1089.8)	1191.6 (508.273)	6.148	.003 *
	High	1384.57 (558.08)	1818.77 (819.72)	1372.97 (788.67)	4.223	.017 *
C	Low	1594.54 (939.72)	1472.83 (791.3)	1007.2 (554.38)	5.555	.005 *
	Med	1530.07 (798.69)	1441.1 (777.95)	1180.07 (644.84)	1.795	.172
	High	1438.43 (722.71)	1545.91 (878.23)	1027.46 (475.7)	5.173	.007 *

** Significant difference between the feedback groups, at p < .05.*

In the first block there were differences for the medium-consequence scenarios, with individuals in the low-feedback group responding significantly slower than those in the high-feedback one (t (68) = 2.451, p = .017, r = 0.28).

For the second block, results showed differences in all three consequence conditions. For the low consequence scenarios, individuals in the high-feedback group responded significantly faster than those in the low- (t (58) = 2.78, p = .007, r = 0.34) and medium-feedback (t (58) = 2.838, p = .006, r = 0.35) ones. For the medium-consequence scenarios, individuals in the high-feedback group responded significantly faster than those in the low- (t (68) = 2.113, p = .038, r = 0.25) and medium-feedback (t (68) = 3.77, p = .000, r = 0.42) ones. Similar significant differences were observed for the high-consequence scenarios, where individuals in the high-feedback group responded significantly faster than those in the medium-feedback one (t (68) = -2.59, p = .012, r = 0.3).

Results also pointed to significant differences between response times in the third block. When faced with low-consequence scenarios, individuals in the high feedback group responded significantly faster than those in the low- (t (68) = 3.185, p = .002, r = 0.36) and medium-feedback (t (68) = 2.851, p = .006, r = 0.11) ones. Similarly, in the high-consequence scenarios, results showed that those in the high-feedback group responded significantly faster than those in the low- (t (68) = 2.81, p = .006, r = 0.32) and medium-feedback (t (68) = 3.071, p = .003, r = 0.35) ones.

Based on the block analysis into possible repetition effects, results showed that the data could confidently be collapsed together and analysis should be carried out on the blocks as a whole (see *Table 4*). Results showed that there were significant differences in the response times in the individual consequences when comparing them between the feedback groups, showing a similar trend for all three scenarios.

Table 4. Mean (SD) response times for each feedback group in all consequence conditions

Consequence Scenario	*Feedback Group*			*Analysis*	
	Low	Medium	High	*F (2, 299)*	*p*
Low	*1765.61 (934.34)*	*1671.8 (845.13)*	*1366.83 (896.08)*	5.456	.005 *
Medium	*1725.5 (950.93)*	*1704.49 (948.67)*	*1286.47 (714.02)*	7.93	.000 *
High	*1485.55 (677.14)*	*1681.84 (848.54)*	*1318.36 (813.66)*	5.395	.005 *

** Significant difference between the feedback groups, at p < .05.*

In the low-consequence condition, individuals in the high-feedback group responded significantly faster than those in the low- (t (198) = 3.08, p = .002, r = 0.21) and medium-feedback (t (198) = 2.476, p = .014, r = 0.17) ones. When faced with medium-consequence scenarios, again individuals in the high-feedback group responded significantly faster than those in the low- (t (198) = 3.684, p = .000, r = 0.25) and medium-feedback (t (198) = 3.513, p = .001, r = 0.24) ones. Finally, results in the high-consequence scenarios showed that individuals in the medium-feedback group responded significantly faster than those in the high-feedback (t (198) = 3.092, p = .002, r = 0.21) one.

For the scale ratings, analysis was carried out again on the blocks collapsed together, based on the findings above. Results here showed that there was a significant difference between most of the scale ratings, with exception of three of the items (see *Table 5*). Due to the distribution of the recorded data, a non-parametric Kruskal-Wallis ANOVA was carried out.

Table 5. Median scale ratings across all three feedback groups

Scale Item	*Feedback Group*			*Analysis*	
	Low	Medium	High	*H (2)*	*p*
% Correct	*10*	*40*	*70*	*33.885*	*.000 **
Concentrate	6	7	7	3.257	.197
Solved	*1*	*3*	*7*	*28.3*	*.000 **
Strategy Rev.	*4*	*7*	*7*	*16.405*	*.000 **
Stressed	8	5	6	4.486	.112
Anxious	7	5	6	4.627	.095
Quickly	7	7	7	2.695	.264
Accurately	7	7	8	5.575	.056

** Significant difference between the feedback groups, at p < .05.*

Mann-Whitney tests were carried out to follow up the significant findings, to identify where the differences were. A Bonferroni correction was applied and so all effects are reported at a .0167 level of significance, in order to look at the significant differences observed for three of the scale items. When asked about how many trials individuals thought they had answered correctly, there was a clear trend, with an increase from the low- to medium feedback groups (U = 8, r = -0.81), and from the medium to high-feedback one (U = 29.5, r = -0.64). Similarly, results showed that individuals in the high-feedback group claimed to have solved the task when compared to those in the medium- (U = 14, r = -0.76) and low-feedback (U = 6, r = -0.83) groups. Finally, individuals in the low-feedback group stated that they rarely revised their strategy based on the feedback provided, especially when compared to the higher ratings given by those in the medium- (U = 43.5, r = -0.53) and high-feedback (U = 22, r = -0.7) groups.

The results for the response times showed that there were some significant differences, which showed a trend across the feedback groups for the particular consequence scenarios, even though pointing to small effect sizes. On the other hand, only a few of the scale items showed significant differences between the feedback groups, pointing to possible weaknesses in identifying the main factors which possibly influenced the behavioural differences.

3.3 Response Times

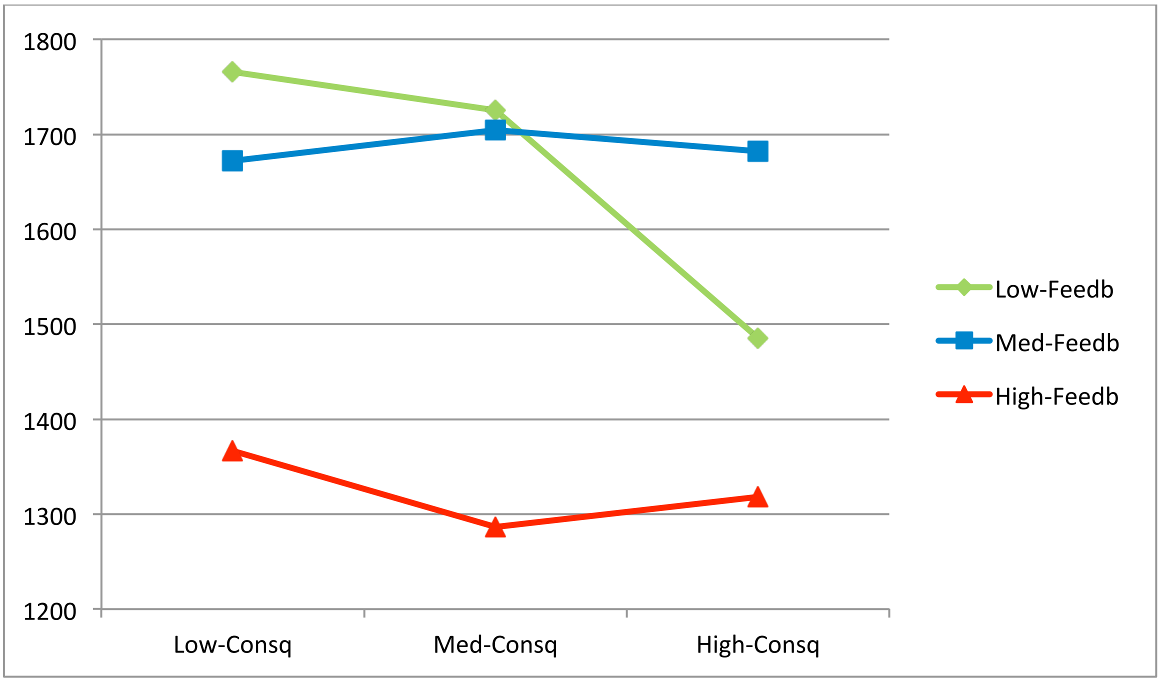
A comparative analysis was carried out between the response times for the different scenarios in each individual feedback group, using a repeated measures ANOVA (see *Table 6*).

Table 6. Mean (SD) response times for each consequence condition in all three feedback groups

Feedback Group	*Consequence Scenario*			*Analysis*	
	Low	Medium	High	F (2, 178)	p
Low	1765.61 (934.34)	1725.5 (950.93)	1485.55 (677.14)	2.032	.134
Medium	1671.8 (845.13)	1704.49 (948.67)	1681.84 (848.54)	0.058	.944
High	1366.83 (896.08)	1286.47 (718.02)	1318.36 (813.66)	1.233	.294

Results showed that there were no significant differences between the response times for the scenario conditions in each of the individual feedback groups (see *Figure 1*).

Figure 1. Mean response times for the three separate feedback groups in each individual consequence scenarios



The recordings showed that there was no significant variation in response times between the consequence conditions, which was observed across all three feedback conditions.

3.4 Task Questionnaire

After completing the decision paradigm, participants filled out a post-task questionnaire. These responses provide a qualitative insight into the decision-making processes and individuals' experience during the experiment, complementary to the behavioural measures.

Asked to rate their feedback level after completing the task (Q.1), individuals in the low-feedback group had a very low rating and felt frustrated with the task ("*It seemed to have no pattern, and was frustrating.*"), while those in the medium-feedback one also gave low ratings as they felt unsure about their performance ("*Couldn't figure out any strategy to complete the task.*"). Those in the high-feedback group rated their task performance as high, even if there was no clarity on their individual strategy ("*I got many of them right... didn't really understand why one response was correct and another incorrect.*").

When asked if they reconsidered their choices at the very last moment (Q.4), individuals in all feedback groups stated that they did not. Similarly, there was a consensus across the groups when asked about the focus of their strategy (Q.5) and the need for more time (Q.6). With no decisions reaching the assigned time-limit available, most individuals moved quickly to operating within the give time frame. This was further reflected their answers, where they stated that accuracy was their main concern while completing the task. Only in the medium-feedback group one individual stated that more time would have allowed them to figure out the pattern ("*With more time I would have been able to properly understand if there was a relationship.*").

When asked about the perceived solvability and difficulty of the task (Q.7), there was a variation in the answers given by each feedback group. Those in the low-feedback one showed frustration with the task, stating it was not solvable and too difficult ("*Not solvable, so very difficult.*"). Individuals in the medium-feedback group were open to the solvability of the task, but stated level of difficulty and varying accuracy as the reasons for their insecurity ("*At the time, no, I found it too difficult but I believe I was looking at it wrongly.*"). Finally, those in the high-feedback group felt that they had solved the task ("*Quite easy once you realised what the solution was.*"), while stating insecurity due to possible change in the solution pattern ("*Pattern seemed to change and it takes a while to work out the new pattern and copy it.*").

In the last question, when asked about the correct solution to the task (Q.8), most in the low-feedback group stated that there was no solution to the task ("*Don't think there was one.*"), while those in the medium-feedback one where unsure about what the correct solution was. Most in the high-feedback group did put forward a theory about what they though the correct solution was, ranging from recognising a pattern ("*... when you saw a bomb and a building you had to choose the opposite length.*") to focusing on a specific wire ("*Cut the red wire.*").

4. DISCUSSION

Results showed that when processing both, contextual information and choice alternatives simultaneously, there are no significant differences observed between the consequence scenarios. This followed up from Experiment 1, addressing questions about task loading and cognitive processing which explained the observations regarding response times, which were against expectations for these types of forced-choice environments. This experiment answered some of the questions relating to the design and validity of the decision paradigm, addressed factors concerning cognitive loading and the effect on behavioural measures of decision-making.

Design

Looking at the reliability of the experimental design, results showed that repetition of the task did not have an effect on performance, with an overall homogenous distribution of the response times and consistent ratings, across both feedback and consequence conditions.

The feedback group individuals were placed in did have a significant effect on their performance, where participants responded significantly faster in the high-feedback condition for all three consequence scenarios. Relating to the results in Experiment 2, this pointed to a raised feedback and accelerated performance, seeing as they mostly received positive feedback to their choices. This was further reflected in some of their personal ratings. Individuals in this group rated their perceived accuracy highest and were most confident about having solved the task. Similarly, individuals in this group stated that they rarely felt the need to revise their strategy. While the differences in ratings were not uniform across the conditions, they did still point to a significant effect the manipulations had on individuals' performance. This was in line with expectations regarding their task mood (Loewenstein, Weber, Hsee, & Welch, 2001; Bagozzi, Dholakia, & Basuroy, 2003), and raised some questions about the design of the experiment.

Finally, when comparing the scenario conditions against each other, results showed that there were no significant differences between them for each of the three feedback groups. This showed, that regardless of the operational setting in which they were making a decisions, there was no difference in terms of the time it took participants to make a choice between the two wires. This pointed to the fact, that when being presented with all the information at once, it took participants the same amount of time to deliberate about their choice and implement it.

Considering this in relation to Experiments 1 and 2, these findings pointed to a further change in behavioural measures. While in the previous experiment there was a difference between the scenarios, results here pointed to the fact that individuals did not vary in their speed when choosing which wire to cut. One explanation for this possibly related to the heightened performance pressure, where all information was presented at once, compressing the time available to evaluate, deliberate or reconsider previous information, before making a choice. The expected delays were not observed between the consequential scenarios.

While the lack of significant differences pointed to a difference in behavioural response, this particular design would not lend itself to be expanded to include EEG measures. The number of stimuli presented simultaneously would overlap and would make it difficult to isolate the individual stages proposed in the current decision-making model. But this format provides an explanatory basis on which to further identify the effect cognitive loading has on evaluation and deliberation, and how these affect the decision-making process and responses. Even when dealing with arbitrary decision problems, the presentation of multiple pieces of information at once clearly leads to delay in processing. But considering this in terms of the operational variations of these problems, consequence scenarios did not have the same effect they did in the other version of this task.

5. CONCLUSION

Following on from findings around the behavioural measures for the forced-choice decision-paradigm, this experiment looked at the effect higher cognitive loading had on response times for the varying consequence scenarios. Results showed that when all information was presented simultaneously, there were no significant differences between the scenarios. Adding to findings from Experiment 1, this further confirmed the idea that individuals engaged cognitively with the problem before reaching the decision phase arbitrarily set in the experiment. Thus, the response times considered solely from the presentation of the choice-stimuli did not reflect a true picture of individuals' processing of task information. This confirmed observations about the early and prolonged deliberation during the more consequential scenarios, and the need to consider longer time intervals prior to the presentation of any information stimuli or the implementation of a choice, in order to get a clearer understanding of the underlying decision-making processes.

Furthermore, results around the feedback manipulations in this set-up showed that they did significantly affect performance. This was in contrast to the findings from Experiment 2, where the same groupings did not seem to affect response times. While there were no neurocognitive measurements available in this experiment, this further pointed to the early engagement with the decision problem, which is not possible when all information is made available simultaneously.

Chapter V

Stroop Advice

Experiment 4

1. INTRODUCTION

The findings in Experiment 1 (see *Chapter II*) showed that individuals engaged in redundant deliberation, even in the absence of meaningful, choice-related information. Results further showed that participants did so with significant differences between the three scenario consequence conditions; showing stronger activity in relation to preparation and planning to respond, as well as faster response times when ultimately committing to a choice. These variations were correlated with the consequential impact of the decision environment indicating a significant effect of emotion on the decision making processing, when lacking other points of reference.

To further assess the different effects consequential impact had on the decision-making process, the experiment was expanded to incorporate variations in the types of task-relevant information made available to individuals. Following a similar set-up, in some instances information was provided in the form of advice in order to identify variations in deliberation and implementation, combining this with the findings on scenario conditions. In other instances, no advice was provided, which provided an additional dimension, lacking task-relevant information, and prompting a shift in response, with participants applying their own strategy to make a decision.

Having established a base-line measure of the experimental decision paradigm and the effect of scenario consequence on performance, the next addition focused on providing information to the decision-making process. The main goal was to identify the cognitive processes relating to the evaluation and deliberation of information, and how this would be reflected in the making of the decision and any possible interaction with the scenario consequences. In order to best isolate this activity, the types of available information were designed in line with research exploring the Stroop Effect. More specifically, the idea behind the reverse Stroop-effect (in which the mismatched colour of the word affects the time needed to identify the *word*) was used, instead of the Stroop Effect (the mismatched colour of the word affects the time needed to identify the *colour* it is displayed in). This Reverse Stroop Effect (RSE) variation provided an indicator of solvability to the task on varying degrees of difficulty (i.e. cognitive processing of the colour conditions).

Experimentally, the Stroop task has long been the ‘gold standard’ of attention (MacLeod, 1992). Regarded as a classic test of response interference, it is based on the principle that reading words is more habitual and automatic than saying the colour (Stroop, 1935; see MacLeod, 1991). In the experiment to be presented here the design followed variations similar to those in the RSE (Stroop, 1935; Experiments 1 & 3), where advice was given in congruent or incongruent conditions. As applied in various research settings in the past (Flowers, 1975; Martin, 1981; Durgin, 2000; Blais & Besner, 2007), this test has been key in developing ideas around attention and cognitive activity, as a means to creating varying conditions. Following on from the original decision task aimed at inducing conflict between the available alternatives (wires) based on the different operational scenario – albeit with no meaningful information to resolve that conflict – this version focused on using attentional activation as an additional reference.

Variations in the Stroop conditions have been identified in terms of the conflict and interference they cause in cognitive processing and behavioural response. EEG and fMRI studies have revealed selective activation of the anterior cingulate cortex during a Stroop task, part of the prefrontal brain structure which has been found to be responsible for conflict monitoring (Carter & van Veen, 2007).

Similarly to traditional theories around interference (Tomlinson, Huber, Riethb, & Davelaarc, 2009), brain activation during Stroop tasks has been observed in the anterior cingulate cortex, supplementary motor cortex, visual association cortex, inferior temporal cortex, inferior parietal cortex, inferior frontal cortex, dorsolateral prefrontal cortex, and caudate nuclei (Peterson, Kane, Alexander, Lacadie, Skudlarski, Leung, Mat, & Gore, 2002). Further, both EEG and fMRI studies, have consistently shown activation in the frontal lobe, and more specifically in the anterior cingulate cortex and dorsolateral prefrontal cortex (Strauss, Sherman, & Spreen, 2006).

It is this conflict-inducing effect that was of interest when using the Stroop effect to provide information during the decision task, in the form of varying types of advice. Following on from findings in Experiment 1, the focus was to further identify activity in the frontal lobe and replicate previous associations of response conflict with activation in the anterior cingulate, especially when comparing incongruent against congruent trials (Bench, Frith, Grasby, Friston, Paulesu, & Frackowiak, 1993; Carter, MacDonald, Botvinick, Ross, Stenger, Noll, & Cohen, 2000; Pardo, Pardo, Janer, & Raichle, 1990). Activation in these areas has been related to their role in executive functions (Bush, Luu, & Posner, 2000), which has also been proposed to describe the deliberation stage of forced-choice decision making environments.

The experiment followed on from previous investigations of the Stroop task using Event-related Potentials (ERPs), highlighting the need to analyse two different time-windows, differentiating between the stimuli presentation and the choice response (Badzakova-Trajkov, Barnett, Waldie, & Kirk, 2009). This set-up followed on from the overall paradigm design, not focusing solely on the cognitive response to the stimuli, but also the effect it had on the implementation of response. Research has suggested that the behavioural Stroop effect may be due to competition at the level of the response (Rosenfeld & Skogsberg, 2006), supporting the *late selection* theoretical accounts, which argue that conflict occurs late in processing, close to the response stage (MacLeod, 1991). More recent studies have lent further support, recording ERPs to assess brain correlates of Stroop interference (N/P450 and sustained potential), respectively reflecting conflict processing and attentional control (Lansbergen, van Hell, & Kenemans, 2007).

The propositions in this experiment were based on the idea that more cognitive-laden (effortful) decision environments (i.e. more consequential scenarios, and incongruent/ambiguous advice) result in larger amplitude and a prolonged period of activation. This would be further reflected in variations in response times, as activation relating to the suppression of immediate response allowed for a longer deliberation. These premises allowed for a robust comparative framework on which to identify particular decision stages and their time distribution, and brain areas active during higher-level decision-making processing, based on the understanding of these executive functions.

The main aim of this experiment was not to replicate and confirm the findings from the Stroop effect, but to rather use the established findings to identify the unique processes and stages of decision-making, based on known attentional activation and response delays. By using the varying types of advice, it was possible to trace the resulting brain activity during the decision-making process over a spectrum where information available required different levels of attention and cognitive effort. These findings were then overlaid on top of those around the effect scenarios consequences had on this forced-choice experimental paradigm, to assess when, and if, the type of information available interacts with the scenario condition in which this advice is presented and how individuals' decision-making processing was affected by this.

1.1 Objectives and Hypotheses

The aim was to look at the combined effect information and consequence scenarios had on cognitive processing and behavioural response during a simplified decision paradigm. Having identified activity relating to the stages of deliberation and implementation in the previous experiments, where no meaningful information was available, the goal here was to assess how different types of information were processed and how they affected individuals' performance in different operational scenarios. The various types of information provided a comparative framework, on which to measure the effects clear, ambiguous and no information had on individuals' choices and how these mapped out on neurocognitive activity, when presented in different consequence scenarios. The following objectives were also considered:

> Identify the neural processes involved at each stage of decision making, and map these out for each individual type of information.

> Emotional stimuli that suggest more significant and consequential outcomes will result in increased and prolonged amplitudes at the stages of deliberation, preparation and implementation.

> The incongruent and no information conditions will result in increased and prolonged amplitudes at the stages of deliberation and implementation, with longer response times, than the congruent information condition. But these two conditions will result in activation of different brain areas, providing a basis on which to differentiate between complex information processing and task-specific problem solving.

2. METHOD

2.1 Participants

Fourteen individuals (7 females, 7 males) participated in the experiment. They ranged in ages from 20 to 30 years, with a mean age of 25 years. Participants were drawn from a sample of students at the University of Liverpool, all without any disclosed health issues, and were all right-handed.

2.2 Procedure

This experiment followed a similar set-up as previous experiments (see *Chapters II, III, and IV*). Participants were seated in a comfortable chair, inside a dim-lit, electrically-shielded room, with their right arm resting on a platform. All task-related information was presented to them on a computer screen, and they used a mouse placed below their right hand to give their responses.

The experiment consisted of a series of decision situations, at the end of which individuals were asked to make a choice between two random alternatives under time pressure. The task consisted of a 'bomb scenario', where participants were asked to imagine themselves operating in the various situations with the objective to 'cut' a wire and disarm a bomb. Following this, they faced a decision stage and had to choose between two alternatives, in the form of two different coloured wires (see *Table 1*) (failing to cut one of the wires at sufficient speed automatically led to 'detonation'). The basic premise of the decision problem focused on a binary negative outcome paradigm, where participants had to choose between two arbitrary alternatives, not knowing which would be the correct wire - reinforced through time constrains and performance pressures - and where a 'wrong' decision lead to a negative outcome.

Varying from the initial design, this experiment only focused on two situational settings. Participants were presented with a context-setting scenario involving either:

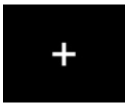
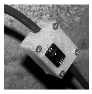
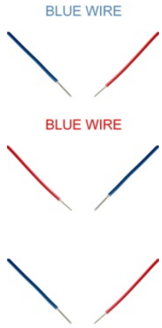
(i) a light-bulb, which they had to switch off by picking a wire (low consequence condition), or
(ii) children on a playground, in which the wires were used to disarm a bomb (high consequence condition).

In summary, the stimulus indicated two conditions: 1) low consequence, and 2) high consequence. This was followed by an image of a light switch (low consequence condition) or explosive device (high-consequence condition), to reinforce the situational context. Finally participants were prompted to choose between a red or blue wire ‘connected’ to the particular device. Failure to make a decision or an incorrect choice, led to detonation of the device. Following each choice, they received feedback in the form of a “*CORRECT*” or “*INCORRECT*” on-screen message.

The instructions, prior and during the experiment, all emphasised the need to take quick and decisive action. Participants were told that they would be assessed on their accuracy as well as their speed, forming part of an overall learning task. As part of this learning task, in some instances they received ‘advice’ on which wire was the correct one; while in others they received no advice, just as in Experiment 1. This information was provided as a direct statement above the two wires (i.e. RED WIRE or BLUE WIRE), varying in the colour they were written in. Following on from propositions about the Reverse Stroop Effect (Stroop, 1935; see MacLeod, 1991), the advice was provided in congruent or incongruent form. Additional advice conditions were considered (e.g. neutral colour, unrelated word), but a no-advice condition was chosen, to remain consistent with previous experiments

A total of 240 stimuli series were presented in two blocks of 22 minutes each, with a 5 minutes break between them. The order in each block of 120 stimuli was randomised, combining both scenario conditions (i.e. low- and high-consequence) with all three advice conditions (i.e. congruent, incongruent, and no advice).

Table 1. Decision Paradigm (example)

STAGE		Evaluation	Deliberation	Choice	
STIMULI	Mask	Context	Device	Decision	Feedback
		 	 		CORRECT or INCORRECT or TOO SLOW
TIME	*2,000ms*	*2,000ms*	*2,000ms*	*3,000ms*	*1,500ms*

2.3 Recordings

EEG was recorded using 64 electrodes in continuous mode on Biosemi (ActiView v6.05, Amsterdam – Netherlands). A band pass filter of 0.16-100 Hz and a sampling rate of 500 Hz were used, while the electrode-to-skin impedance was kept below 5 kΩ. Elecrooculography (EOG) measures were recorded, using electrodes placed above and below the left eye, while electrocardiographic (ECG) measures were recorded by placing one electrode on the right ankle and another one on the left wrist. Both of these recordings were used to account for any artefacts in the data analysis.

The decision scenarios were designed using Inquisit (Millisecond Software v3.0.4, Seattle – USA), and recordings for each participant's response times were taken at each decision stage.

2.4 Data Analysis

Averaged EEG epochs were segmented after band pass filtering and analyzed using the Brain Electrical Source Analysis (BESA) program (MEGIS Software, Munich – Germany). Trials containing ECG artefacts or large EOG variations (> 75 mV) were discarded from further analysis. There were two vision-related measures, with one focusing on the presentation of scenario context stimuli and the other on the advice stimuli. For the scenario-related measures, 3,045 averaged EEG epochs were segmented to a length of 1,100 ms (100 ms pre- to 1, 000 ms post-stimulus), while for the advice-related measures, 3,234 averaged EEG epochs were segmented to a length of 800 ms (200 ms pre- to 600 ms post-stimulus). For the movement-related measures, 3,067 averaged EEG epochs were segmented to a length of 2,000 ms (1,500 ms pre- to 500 ms post-stimulus). A source model of the EEG potentials was constructed from the grand average data (N = 14) for each of the measures. The data were transformed into the Talairach coordinate system, and the locations of the EEG sources were evaluated for each individual dipole (Talairach Client v2.4.2, Research Imaging Centre, UTHSCSA - USA).

2.5 Statistical Analysis

The effect of stimulus intensity on the dipoles source was analysed using a paired-samples t-test for the scenario conditions, comparing the recordings following stimuli presentations. The independent variables at this stage were the two different scenario conditions (low- and high-consequence). For the latter stages, advice presentation and choice commitment, the stimulus intensity on the dipoles source was analysed using a factorial repeated-measures analysis of variance (ANOVA). The independent variables for both included again the scenario conditions (high and low), and additionally the three different types of advice (congruent, incongruent, and no advice).

3. RESULTS

Results will detail three stages for each decision task within the experiment, describing the differences in amplitudes for each of the source dipoles, directly following the presentation of stimuli or the commitment to a choice. First, the focus will be on the perception components relating to the presentation of the context-setting stimuli, indicating the scenario in which individuals were 'operating'. Further, the focus will be on the perception components relating to the advice provision and, finally, on the activity prior to the button press and commitment to a choice. For all of these stages, the data will be compared based on the two consequence conditions, looking for significant difference in the source waveforms. Similarly, the second and third stages will additionally consider the differences in advice provision, while also looking at any significant interaction. Additionally, behavioural and qualitative measures will be analysed, to further expand on the decision-making narrative.

3.1 Perception Components

3.1.1 Scenario Consequence

Five regional source dipoles were fitted to describe the 3-dimensional source currents contributing to the data (see *A, Figure 1*). Three sources were located in the occipital lobe. The central source (S1, Talairach coordinates in mm [x: -11.6, y: -65, z: -13.5], Brodmann area 19) peaked at 100ms. Two secondary sources, occupying lateral locations in the occipital lobe ($S2_R$ [x: 34.4, y: -66.9, z: 3.1], 10, and $S3_L$ [x: -29.5, y: -91.3, z: -2.2], 18) peaked at 129ms and 267ms respectively. Another source was located in the posterior cingulate cortex (S4 [x: 9.7, y: -27.1 z: 37.8], 31), peaking at 482ms. While the last source was located in the frontal lobe (S5 [x: -11.1, y: 55.4, z: 32.3], 10) and peaked at 117ms. The grand-average model was tested for all conditions, and the residual variances were similar in both conditions (both 15%, low-consequence 21%, high-consequence 13%) (see *B*, in *Figure 1*).

To evaluate the differences between the two scenario conditions, individual source waveforms for each were obtained using the grand-average model. The average source waveforms with time intervals showing statistically significant deviation ($p < 0.05$) between the different conditions are shown in Figure 1.

Scenario conditions were associated with statistically significant differences of source dipole amplitude in the source located in the posterior lobe (S1) for three different time intervals. An early interval (120ms to 190ms) showed that high-consequence scenarios resulted in a larger increase in amplitude than the low-consequence ones, $t = -7.706$, $p = .00$. The later interval (470ms to 560ms) showed that high-consequence scenarios resulted in a larger increase in amplitude than the low-consequence ones, $t = -3.831$, $p = .00$. The last interval (690ms to 810ms) again showed that high-consequence scenarios resulted in a larger increase in amplitude than the low-consequence ones, $t = -7.157$, $p = .00$.

Similar significant differences were observed at both lateral source dipoles ($S2_R$ & $S3_L$) located in the occipital lobe, when looking at two similar time intervals for both. Amplitudes for the ipsilateral source dipole ($S2_R$) showed that high-consequence scenarios resulted in a larger decrease in amplitude than the low-consequence ones, $t = 8.5896$, $p = .00$, in an early interval (160ms to 360ms). A later one (400ms to 560ms) at the same source showed that low-consequence scenarios resulted in a larger increase in amplitudes than the high-consequence ones, $t = 7.8476$, $p = .00$. Similarly, amplitudes for the contralateral source dipole ($S3_L$) showed significant differences for two separate time intervals. An early interval (160ms to 340ms) showed that high-consequence scenarios resulted in a larger increase in amplitude than the low-consequence ones, $t = -8.705$, $p = .00$. The later interval (390ms to 570ms) showed similar differences, where high-consequence scenarios resulted in a larger increase in amplitude than low-consequence ones, $t = -8.0254$, $p = .00$.

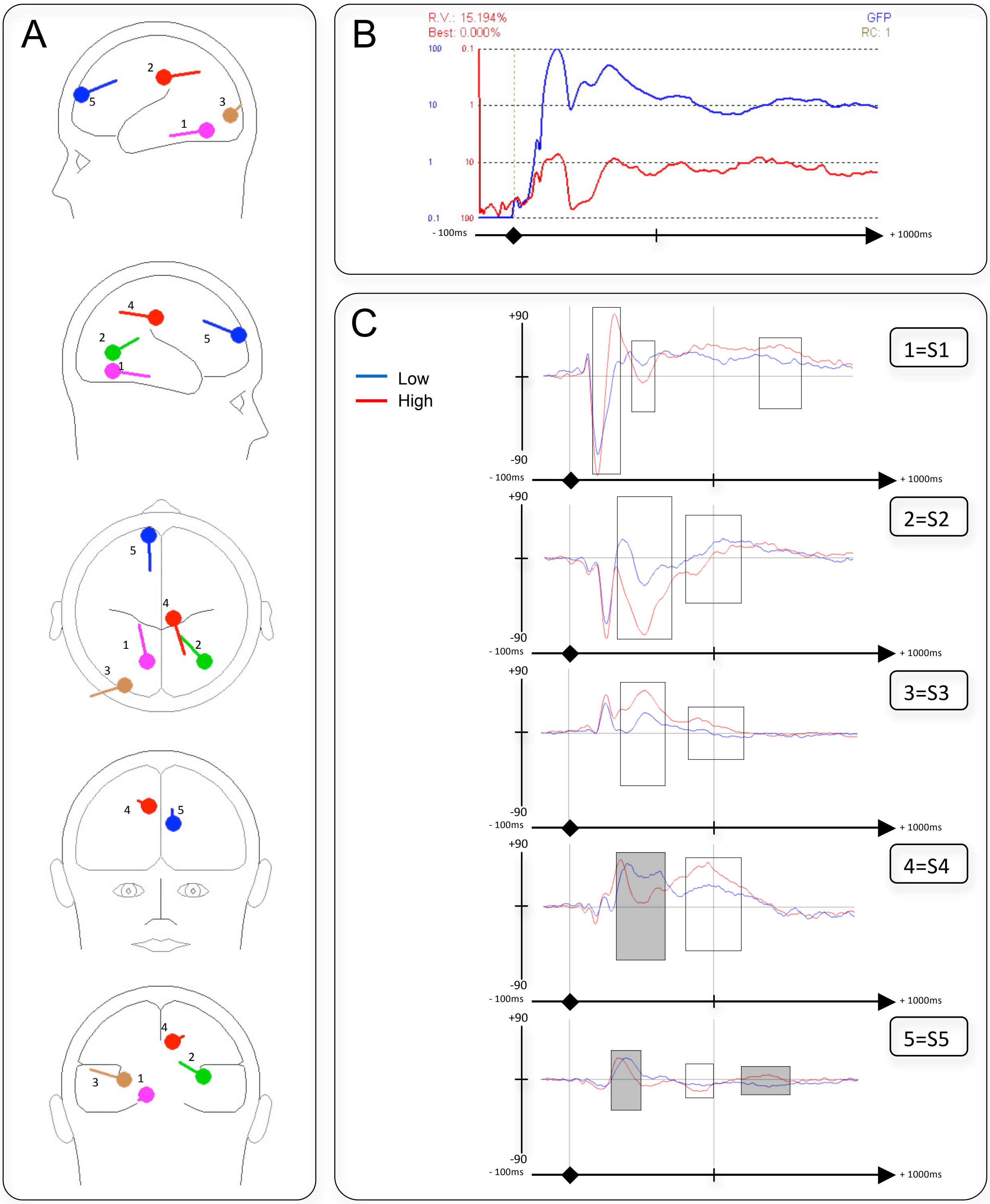
Table 2. Mean activity recorded for perception components with significant differences between consequence conditions

Source	*Consequence Scenario*		Analysis	
	Low	High	*t*	*p*
S1.1 (120ms – 190ms)	M = -7.68, SD = 24.62	M = 27.92, SD = 34.53	-7.706	.000
S1.2 (470ms – 560ms)	M = 13.76, SD = 12.4	M = 25.21, SD = 17.27	-3.831	.00
S1.3 (680ms – 780ms)	M = 12.89, SD = 11.75	M = 23.67, SD = 11.75	-7.157	.000
S2.1 (160ms – 360ms)	M = -5.05, SD = 18.46	M = -35.82, SD = 24.72	8.5896	.000
S2.2 (400ms – 560ms)	M = 6.58, SD = 12.16	M = -3.43, SD = 13.01	7.8476	.000
S3.1 (160ms – 340ms)	M = 8.1, SD = 11.95	M = 25.06, SD = 15.43	-8.705	.000
S3.2 (390ms – 570ms)	M = 0.25, SD = 5.38	M = 7.95, SD = 8.09	-8.0254	.000
S4.1 (200ms – 320ms)	M = 28.89, SD = 12.73	M = 9.92, SD = 17.34	8.3843	.000
S4.2 (370ms – 540ms)	M = 14.73, SD = 14.8	M = 30.09, SD = 15.09	-6.5497	.000
S5.1 (200ms – 300ms)	M = 7.71, SD = 8.12	M = -1.12, SD = 6.45	6.8656	.000
S5.2 (420ms – 480ms)	M = -4.56, SD = 5.5	M = -9.58, SD = 7.61	4.0869	.000
S5.3 (670ms – 750ms)	M = -5.45, SD = 7.72	M = 2.21, SD = 4.24	3.3592	.00

Analysis for the source dipoles in the cingulate cortex (S4) and the parietal lobe (S5) showed again significant differences between the scenarios conditions. Recordings for an early time interval in the cingulate cortex (200ms to 320ms) showed that the low-consequence scenarios resulted in a larger increase in amplitude than high-consequence ones, t = 8.3843, p = .00. A later interval (370ms to 540ms) in the same source showed that here the high-consequence scenarios resulted in a larger increase in amplitude when compared to the low-consequence ones, t = -6.5497, p = .00.

Finally, recordings in the parietal lobe (S5) showed again significant differences for three separate time intervals. An early interval (200ms to 300ms) showed that the low-consequence scenarios resulted in a larger increase in amplitude than high-consequence ones, t = 6.8656, p = .00. A later interval (420ms to 480ms) showed that the high-consequence scenarios resulted in a larger decrease in amplitude that low-consequence ones, t = 4.0869, p = .00. On the other hand, recordings for another late interval (670ms to 750ms) showed that low-consequence scenarios resulted in a larger decrease in amplitude than did high-consequence ones, $t = -3.3592$, $p = .00$.

Figure 1. Scenario Consequence Components
(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Occipital Lobe; 3 = S3 Occipital Lobe; 4 = S4 Cingulate Cortex; 5 = S5 Frontal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each scenario condition overlaid (low-consequence = blue; high-consequence = red). Empty rectangles indicate statistically significant (p < .05) increase for source amplitudes in more consequential scenario conditions, while filled rectangles indicate statistically significant (p < .05) decrease for source amplitudes in more consequential ones. Numbers of source waveforms correspond to (A).



3.1.2 Advice

For the advice perception-related components associated with the advice stimuli six regional source dipoles were fitted to describe the 3-dimensional source currents (see *A*, in *Figure 2.1* and *Figure 2.2*). Again, three sources were located in the occipital lobe. The central source (S1 [x: 10.3, y: -73.8, z: 18.6], 18) peaked at 168ms. Two secondary sources, occupying lateral sources ($S2_L$ [x: -38.7, y: -72, z: -20.9], 18, and $S3_R$ [x: 25.8, y: -85.4, z: -2.6], 18) peaked at 230ms and 246ms respectively. A fourth source was located in the contralateral temporal lobe (S4 [x: -39.6, y: -34.6, z: 17.8], 41), peaking at 186ms. The fifth source was located in the anterior cingulate cortex (S5 [x: 7, y: 32.9, z: 14.4], 32), and peaked at 365ms. A final source was located in the ipsilateral inferior temporal lobe (S6 [x: 35.6, y: 2.4, z: -26.3], 38), peaking at 250ms. The grand-average model was tested for all conditions, and the residual variances were similar in all low- (all 10%, congruent 11%, incongruent 13%, no advice 12%) as well as high-consequence advice conditions (all 11%, congruent 12%, incongruent 12%, no advice 14%) (see B, in *Figure 2.1* and *Figure 2.2* respectively).

Same as above, the individual source waveforms for both consequence levels and all three advice conditions were obtained using the grand-average model, in order to evaluate the differences between them. The average source waveforms with time intervals showing statistically significant deviation ($p < 0.05$) between the different conditions are shown in Figure 2.1 and Figure 2.2.

Consequence

Analysis showed that only recordings for one of the source dipoles resulted in significant differences for the amplitudes in the two scenario conditions. For the congruent advice conditions, two intervals with significant differences were identified. An early interval (150ms to 250ms) located in the occipital lobe (S1) showed that low-consequence scenarios (M = -14.13, SD = 17.59) resulted in a larger decrease in amplitude than the high-consequence ones (M = -9.44, SD = 17.32), t = -2.395, p = .032. A later interval (360ms to 420ms) in the same source dipole showed again that low-consequence scenarios (*M* = -9.53, *SD* = 13.28) resulted in a larger decrease in amplitude than the high-consequence ones (*M* = -5.08, *SD* = 10.59), *t* = -3.448, *p* = .004.

Table 3. Mean activity recorded for advice-perception components with significant differences between consequence conditions, for all three advice conditions

Stroop Advice	Source	*Consequence Scenario*		Analysis	
		Low	High	*t*	*p*
Congruent	S1.1 (150ms – 250ms)	M = -14.13, SD = 17.59	M = -9.44, SD = 17.32	-2.395	.032
	S1.2 (360ms – 420ms)	M = -9.53, SD = 13.28	M = -5.08, SD = 10.59	-3.448	.004
Incongruent	S1.2 (360ms – 420ms)	M = -11.57, SD = 14.62	M = -5.66, SD = 12.94	-5.011	.000
None	S1.1 (150ms – 250ms)	M = -15.45, SD = 17.04	M = -9.4, SD = 16.01	-3.823	.002

For the incongruent advice conditions, the later interval (360ms to 420ms) showed that the low-consequence condition (*M* = -11.57, *SD* = 14.62) resulted in a larger decrease in amplitude than the high-consequence ones (*M* = -5.66, *SD* = 12.94), *t* = -5.011, *p* = .000. Finally, when looking at the no-advice condition, the early interval (150ms to 250ms) showed similar differences to those found for the congruent one. Here the low-consequence scenarios (*M* = -15.45, *SD* = 17.04) resulted in a larger decrease in amplitude than the high-consequences ones (*M* = -9.4, *SD* = 16.01), *t* = -3.823, *p* = .002. Analysis for the other 5 source dipoles showed no significant differences between the consequence scenarios in any of the different advice conditions.

Advice

When looking at significant differences between the three advice conditions, all results were reported based on the more conservative Greenhouse-Geisser correction, as the assumption of sphericity was violated for a number of the recordings.

When looking at the low-consequence scenarios, advice conditions were associated with statistically significant differences in a number of source dipoles. An early time interval (100ms to 230ms) in the occipital lobe ($S2_L$) showed that there was a significant effect of the advice condition on the recorded activity, *F* (1.591, 20.682) = 41.139, *p* = .000. Contrasts revealed that the no-advice conditions resulted in a larger increase in amplitude when compared to the congruent, *F* (1, 13) = 29.226, *p* = .000, and incongruent, *F* (1, 13) = 53.395, *p* = .000, ones. A similar time interval (100ms to 230ms) in the occipital lobe ($S3_R$) showed that there was a significant effect of the advice condition on the recorded activity, *F* (1.821, 23.676) = 23.195, *p* = .000. Contrasts revealed again that the no-advice conditions resulted in a larger increase in amplitude when compared to the congruent, *F* (1, 13) = 29.226, *p* = .000, and incongruent, *F* (1, 13) = 53.395, *p* = .000, ones.

Two time intervals for the source dipole located in the temporal lobe (S4), showed a significant effect of the advice condition on the activity recorded. One difference was observed for the early interval (100ms to 190ms), *F* (1.461, 18.987) = 27.881, *p* = .000, which showed that the no-advice condition resulted in a larger increase in amplitude than did the congruent, *F* (1, 13) = 18.331, *p* = .001, and incongruent, *F* (1, 13) = 109.676, *p* = .000, ones. The later time interval (280ms to 350ms) showed again a significant difference, *F* (1.367, 17.772) = 7.661, *p* = .008, where the no-advice condition resulted in a larger decrease in amplitude than did the congruent, *F* (1, 13) = 6.839, *p* = .021, and incongruent, *F* (1, 13) = 10.93, *p* = .006, ones.

For the activity recorded in the ipsilateral temporal lobe (S6), again two separate time intervals showed a significant effect of the advice conditions on the activity recorded. An early interval (90ms to 200ms) showed a significant difference, *F* (1.804, 23.447) = 8.298, *p* = .002, where contrasts showed that the no-advice condition resulted in a larger increase in amplitude than did the congruent, *F* (1, 13) = 7.626, *p* = .016, and incongruent, *F* (1, 13) = 20.552, *p* = .001, ones. Another difference was observed for a later interval (250ms to 350ms), *F* (1.203, 15.641) = 4.426, *p* = .046, where the incongruent advice condition resulted in a larger decrease in amplitude when compared to the no-advice one, *F* (1, 13) = 5.274, *p* = .039.

Table 4. Mean activity recorded for advice-perception components with significant differences between advice conditions, for both consequence scenarios

Consequence Scenario	Source	*Stroop Advice*			Analysis
		Congruent	Incongruent	None	
Low	S2 (100ms – 230ms)	M = 8.3, SD = 16.78	M = 6.96, SD = 16.05	M = -9.57, SD = 15.47	F (1.591, 20.682) = 41.139, p = .000
	S3 (100ms – 200ms)	M = 9.5, SD = 17.43	M = 8.9, SD = 19.67	M = 19.1, SD = 19.08	F (1.821, 23.676) = 23.195, p = .000
	S4.1 (100ms – 190ms)	M = 5.44, SD = 19.98	M = 1.66, SD = 19.38	M = 15.87, SD = 17.63	F (1.461, 18.987) = 27.881, p = .000
	S4.2 (280ms – 350ms)	M = -4.02, SD = 15.65	M = -2.79, SD = 11.18	M= -15.15, SD = 17.51	F (1.367, 17.772) = 7.661, p = .008
	S6.1 (90ms – 200ms)	M = 6.54, SD = 23.88	M = 3.96, SD = 23.81	M = 18.14, SD = 18.46	F (1.804, 23.447) = 8.298, p = .002
	S6.2 (250ms – 350ms)	M = -23.87, SD = 30.29 *	M = -24.68, SD = 26.49	M = -4.68, SD = 27.13	F (1.203, 15.641) = 4.426, p = .046
High	S1.1 (350ms – 450ms)	M = -7.72, SD = 9.52	M = -7.62, SD = 11.26	M = -14.97, SD = 14.09	F (1.383, 17.984) = 4.849, p = .031
	S1.2 (520ms – 590ms)	M = -15.69, SD = 9.75	M = -13.71, SD = 8.82 *	M = -8.08, SD = 10.36	F (1.313, 17.067) = 4.890, p = .033
	S2 (100ms – 230ms)	M= 6.92, SD = 14.47	M = 5.01, SD = 18.21	M = -8.08, SD = 13.49	F (1.368, 17.779) = 16.258, p = .000
	S3 (100ms – 200ms)	M = 11.48, SD = 17.31	M = 9.59, SD = 19.07	M = 17.61, SD = 17.49	F (1.248, 16.225) = 5.883, p = .022
	S4.1 (100ms – 190ms)	M = 9.09, SD = 19.86	M = 6.25, SD = 18.74	M = 14.09, SD = 15.03	F (11.867, 24.277) = 7.919, p = .003
	S5 (180ms – 280ms)	M = 15.52, SD = 15.38	M = 15.51, SD = 14.55	M = 5.11, SD = 22.45	F (1.221, 15.872) = 4.807, p = .037
	S6.1 (90ms – 200ms)	M = 11.75, SD = 24.09 *	M = 6.99, SD = 22.52	M = 19.74, SD = 16.92	F (1.482, 19.262) = 6.224, p = .013
	S6.2 (250ms – 350ms)	M = -27.15, SD = 26.17	M = -26.72, SD = 22.53	M = -5.87, SD = 26.35	F (1.417, 18.417) = 7.397, p = .008

** Differences for these conditions were not statistically significant when compared to the other two, at p < .05.*

When considering the high-consequence scenarios, advice conditions were again associated with statistically significant differences in a number of source dipoles. One of the source dipoles located in the occipital lobe (S1) showed that there was a significant effect of the advice condition on the recorded activity, F (1.383, 17.984) = 4.849, p = .031, for one time interval (350ms to 450ms). Contrasts showed that again the no-advice condition resulted in a larger decrease in amplitude than did the congruent, F (1, 13) = 5.384, p = .037, and incongruent, F (1, 13) = 5.522, p = .035, ones. A later interval (520ms to 590ms) at the same source dipole showed that there was again a significant difference between the advice conditions, F (1.313, 17.067) = 4.890, p = .033, where the congruent advice condition resulted in a larger decrease in amplitude than did the no-advice one, F (1, 13) = 7.592, p = .016.

Analysis for two other source dipoles within similar time intervals again showed that advice conditions were associated with significant differences. An early time interval (100ms to 230ms) in the occipital lobe ($S2_L$) showed that there was a significant effect of the advice condition on the activity recorded, F (1.368, 17.779) = 16.258, p = .000, with contrasts showing that the no-advice condition resulted in a larger decrease in amplitude than did the congruent, F (1, 13) = 25.644, p = .000, and incongruent, F (1, 13) = 13.472, p = .003, ones. Similarly, an early interval (100ms to 200ms) for the source dipole located in the occipital lobe ($S3_R$) showed a significant difference between the advice conditions, F (1.248, 16.225) = 5.883, p = .022. Contrasts here showed that the no-advice condition resulted in a larger increase in amplitude than the congruent, F (1, 13) = 6.003, p = .029, and incongruent, F (1, 13) = 6.534, p = .024, ones.

Another source was located at the temporal lobe (S4) and an early interval around its peak (100ms to 190ms) showed a significant effect for the advice condition, F (11.867, 24.277) = 7.919, p = .003. Contrasts for this interval showed that the no-advice condition resulted in a larger increase in amplitude than did the congruent, F (1, 13) = 5.464, p = .036, and incongruent, F (1, 13) = 21.041, p = .001, ones.

The source located in the anterior cingulated (S5) showed a significant effect for the advice conditions on the activity recorded, F (1.221, 15.872) = 4.807, p = .037, at one particular time interval (180ms to 280ms). Contrasts showed that the no-advice condition resulted in a larger increase for the congruent, F (1, 13) = 5.5, p = .036, and incongruent, F (1, 13) = 4.866, p = .046, advice conditions when compared to the no-advice one.

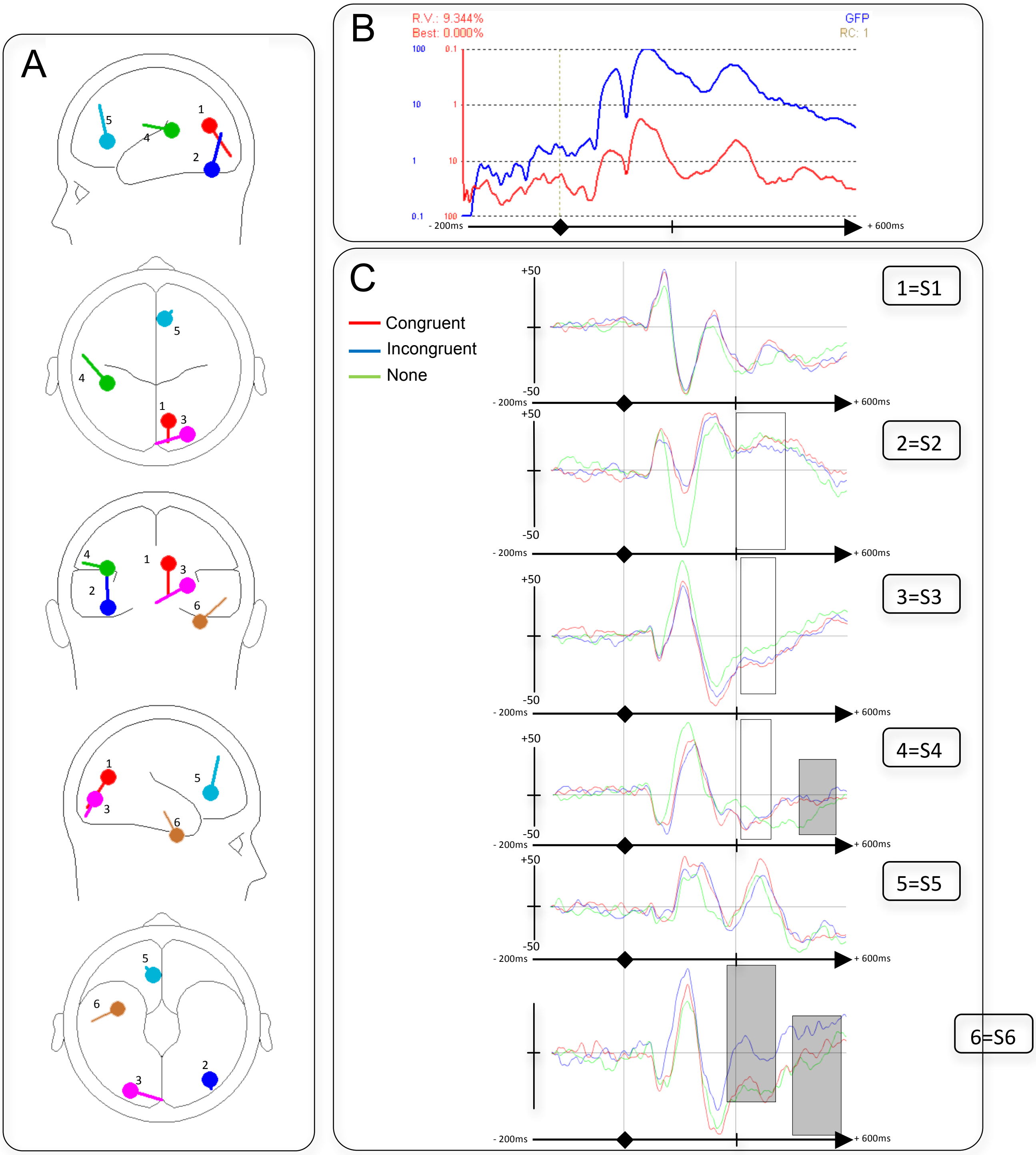
The last source dipole was located in the temporal lobe (S6) and showed a significant effect for the advice conditions at two separate time intervals. An early time interval (90ms to 200ms) pointed to significant differences, F (1.482, 19.262) = 6.224, p = .013, where the no-advice condition resulted in a larger increase in amplitude than the incongruent one, F (1, 13) = 10.769, p = .006. Significant differences were also observed at a later interval (205ms to 350ms), F (1.417, 18.417) = 7.397, p = .008. Contrasts revealed that the congruent, F (1, 13) = 8.666, p = .011, and incongruent, F (1, 13) = 8.138, p = .014, advice conditions resulted in a larger decrease in amplitude when compared to the no-advice one.

Interaction between Consequence and Advice

Further analysis showed that there was no significant interaction between the type of advice given and the scenario conditions in which they were received, when looking at the recorded activity before and after the presentation of the wires. The lack of interaction at this stage of the decision-making process is due to the details received for each of the scenario conditions, and the lack of significant differences between the types of advice conditions, in terms of form and characteristics.

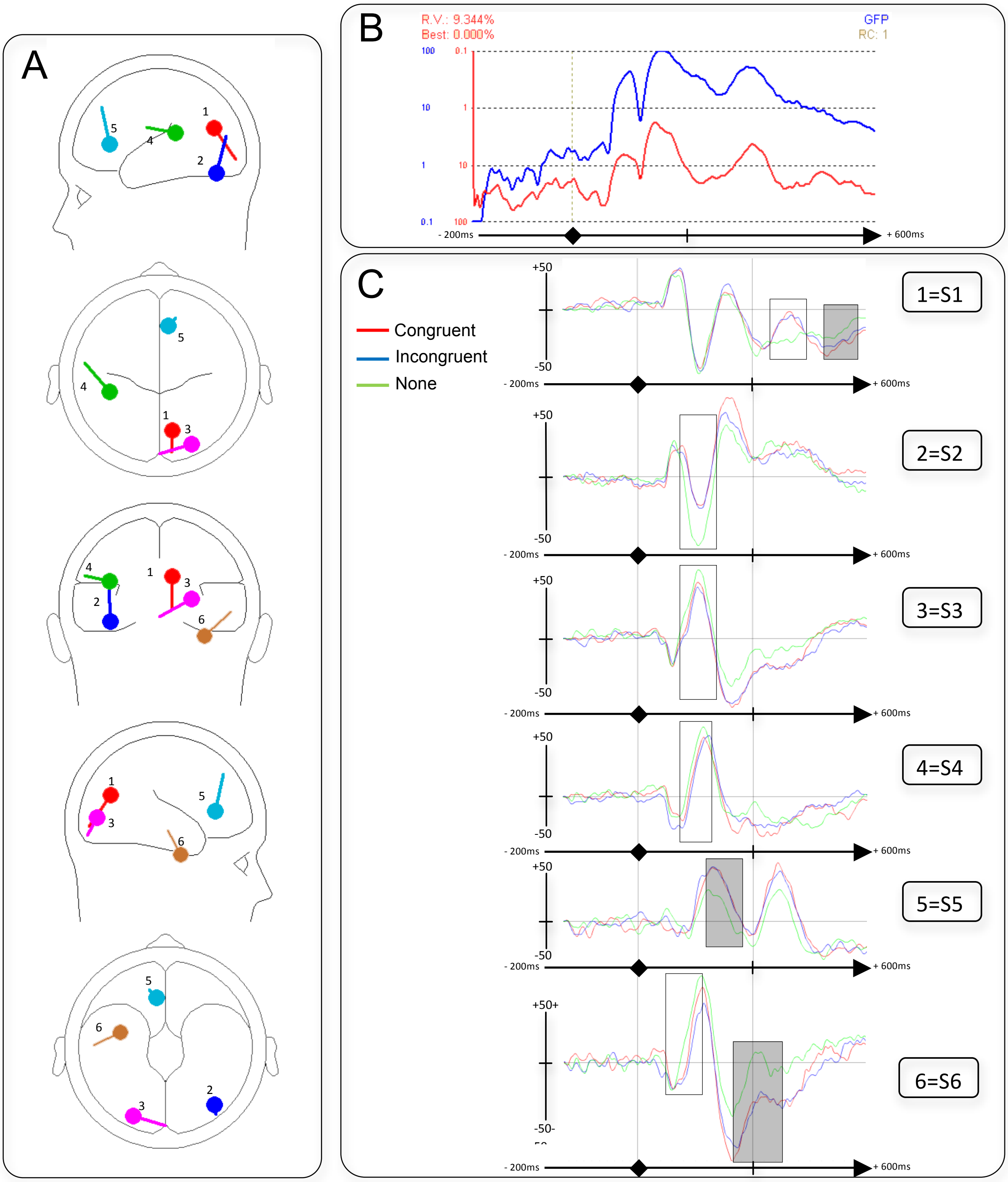
Figure 2.1. Difference between the advice conditions for the advice-perception components when presented in the low-consequence scenarios

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Occipital Lobe; 3 = S3 Occipital Lobe; 4 = S4 Temporal Lobe; 5 = S5 Cingulate Cortex; 6 = S6 Temporal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each advice condition overlaid (congruent = red; incongruent = blue; none = green). Empty rectangles indicate statistically significant (p < .05) increase for source amplitudes in the no-advice conditions, while filled rectangles indicate statistically significant (p < .05) decrease for source amplitudes in the no-advice ones. Numbers of source waveforms correspond to (A).



<u>Figure 2.2.</u> Difference between the advice conditions for the advice-perception components when presented in the high-consequence scenarios

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Occipital Lobe; 3 = S3 Occipital Lobe; 4 = S4 Temporal Lobe; 5 = S5 Cingulate Cortex; 6 = S6 Temporal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each advice condition overlaid (congruent = red; incongruent = blue; none = green). Empty rectangles indicate statistically significant (*p* < .05) increase for source amplitudes in the no-advice conditions, while filled rectangles indicate statistically significant (*p* < .05) decrease for source amplitudes in the no-advice ones. Numbers of source waveforms correspond to (A).



3.2 Decision Components

Movement-related: Choice

For the last part of the analysis relating to the EEG recordings, three regional source dipoles were fitted to describe the source currents (see *A*, in *Figure 3.1* and *Figure 3.2*). One source was located in the occipital lobe (S1 [x: 17, y: -60.4, z: -3.1], 19), peaking at -369ms. The second sources was located in the contralateral primary motor cortex (S2 [x: -27.1, y: -23.2, z: 59.6], 4) and peaked at 123ms. The final source was located in the frontal lobe (S3 [x: -17, y: 50.8, z: 23.3], 10), peaking at 21ms. The grand-average model was tested for all conditions, and the residual variances were similar in all low- (all 49%, congruent 42%, incongruent 45%, no advice 61%) as well as high-consequence advice conditions (all 56%, congruent 53%, incongruent 54%, no advice 62%) (see *B*, in *Figure 3.1* and *Figure 3.2* respectively).

To evaluate the differences between both consequence levels and all three advice conditions, individual source waveforms for each were obtained using the grand average model. The average source waveforms with time intervals showing statistically significant deviation ($p < 0.05$) between the different conditions are show in the figures below. Analysis of the selected Bereitschaftspotential parameters was performed, using a three-way ANOVA for repeated measures at both low- and high-consequence scenarios, factoring in all three advice types. The focus was on particular time intervals, prior to the participants' voluntary movements, identifying their commitment to a particular choice through movement-related potentials (see *C*, in *Figures 3.1* and *Figure 3.2* respectively).

Consequence

Analysis for the last component focused on the activity leading up to the commitment to a decision, describing the shifting activity from deliberation to choice. Results showed that there was only one source (S1) where the scenario conditions resulted in significant differences, and this was only observed for the congruent and incongruent advice conditions.

Table 5. Mean activity recorded for movement components with significant differences between consequence conditions, for all advice conditions

Stroop Advice	Source	*Consequence Scenario*		Analysis	
		Low	High	*t*	*p*
Congruent	S1 (-780ms – -690ms)	M = 3.64, SD = 20.06	M = -5.94, SD = 23.58	2.783	.016
Incongruent	S1 (-780ms – -690ms)	M = 10.48, SD = 25.37	M = -2.82, SD = 18.51	2.82	.014

In the congruent advice condition, results showed a difference between the scenario conditions at an interval prior to the commitment to a choice (-780ms to -690ms), $t = 2.783$, $p = .016$, where the high-consequence scenario resulted in a larger decrease in amplitude than the low-consequence one. On the other hand, the difference for the incongruent advice in the same interval, $t = 2.82$, $p = .014$, showed that the low-consequence scenario resulted in a larger increase in amplitude than the high-consequence one.

Advice

Analysis for the activity based on the three advice conditions for the same component showed again that only the source dipole located in the occipital lobe (S1) resulted in significant differences during one time interval (-650ms to -550ms). The significant effect of advice condition in the low-consequence scenario, F (2, 26) = 12.713, p = .000, showed that the no-advice condition resulted in a larger decrease in amplitude when compared to the congruent, $F(1, 13) = 12.247$, $p = .004$, and incongruent, $F(1, 13) = 17.686$, $p = .001$, ones.

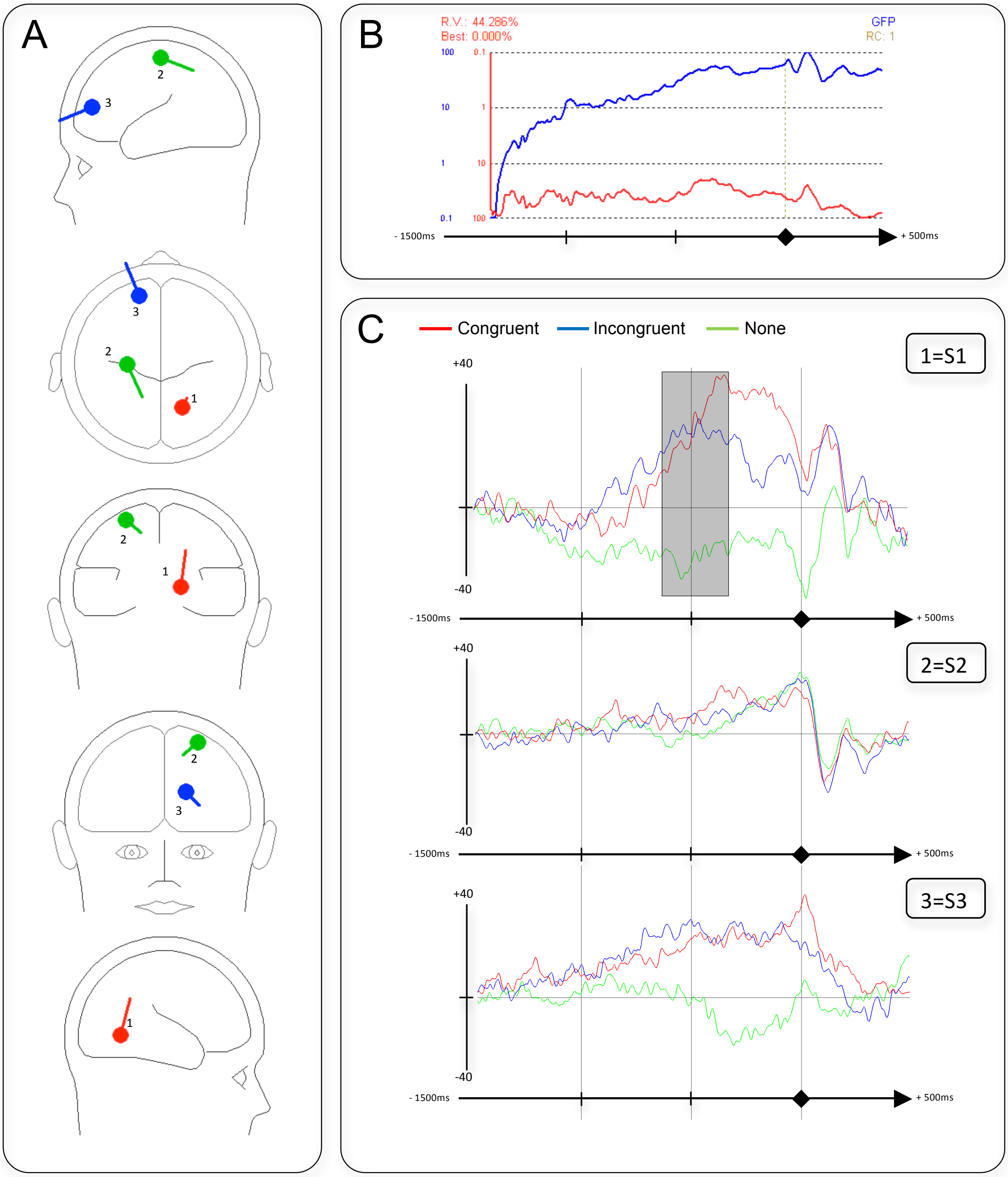
Table 6. Mean activity recorded for movement components with significant differences between advice conditions, for both consequence scenarios

Consequence Scenario	Source	*Stroop Advice*			Analysis	
		Congruent	Incongruent	None	*F* (2, 26)	*p*
Low	S1 (-650ms – -550ms)	M = 12.48, SD = 22.65	M = 17.52, SD = 26.88	M = -13.31, SD = 21.93	12.713	.000
High	S1 (-650ms – -550ms)	M = 1.95, SD = 21.04	M = 4.58, SD = 20	M = -14.04, SD = 14.98	5.293	.012

Similarly, analysis for the high-consequence scenarios, F (2, 26) = 5.293, p = .012, showed that the no-advice condition resulted in a larger decrease in amplitude than the congruent, F (1, 13) = 8.067, p = .014, or incongruent, F (1, 13) = 7.999, p = .014, one.

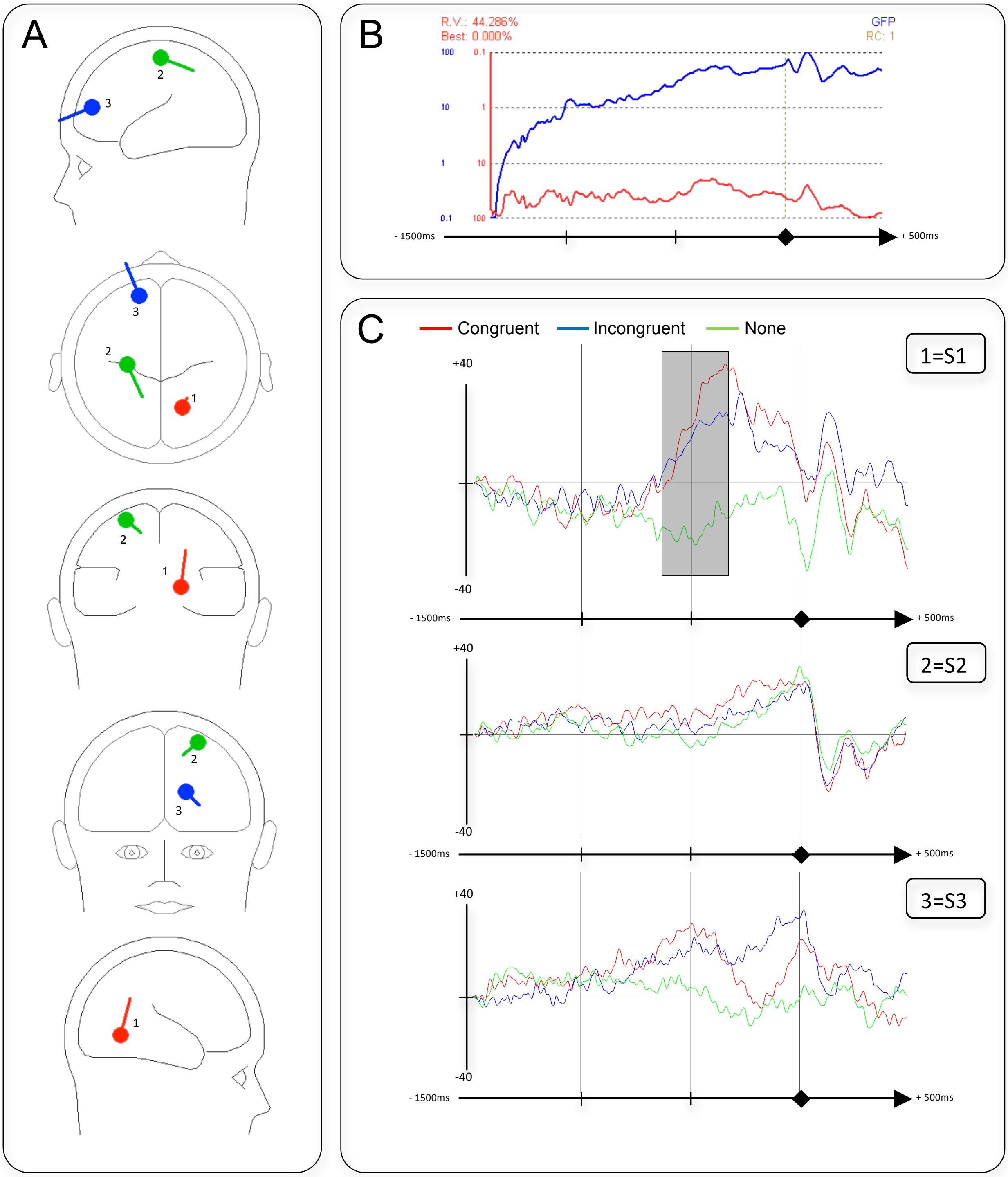
Figure 3.1 Difference between the advice conditions for the movement components when presented in the low-consequence scenarios

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Primary Motor Cortex; 3 = S3 Frontal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each advice condition overlaid (congruent = red; incongruent = blue; none = green). Empty rectangles indicate statistically significant ($p < .05$) increase for source amplitudes in the no-advice conditions, while filled rectangles indicate statistically significant ($p < .05$) decrease for source amplitudes in the no-advice ones. Numbers of source waveforms correspond to (A).



<u>Figure 3.2</u> Difference between the advice conditions for the movement components when presented in the high-consequence scenarios

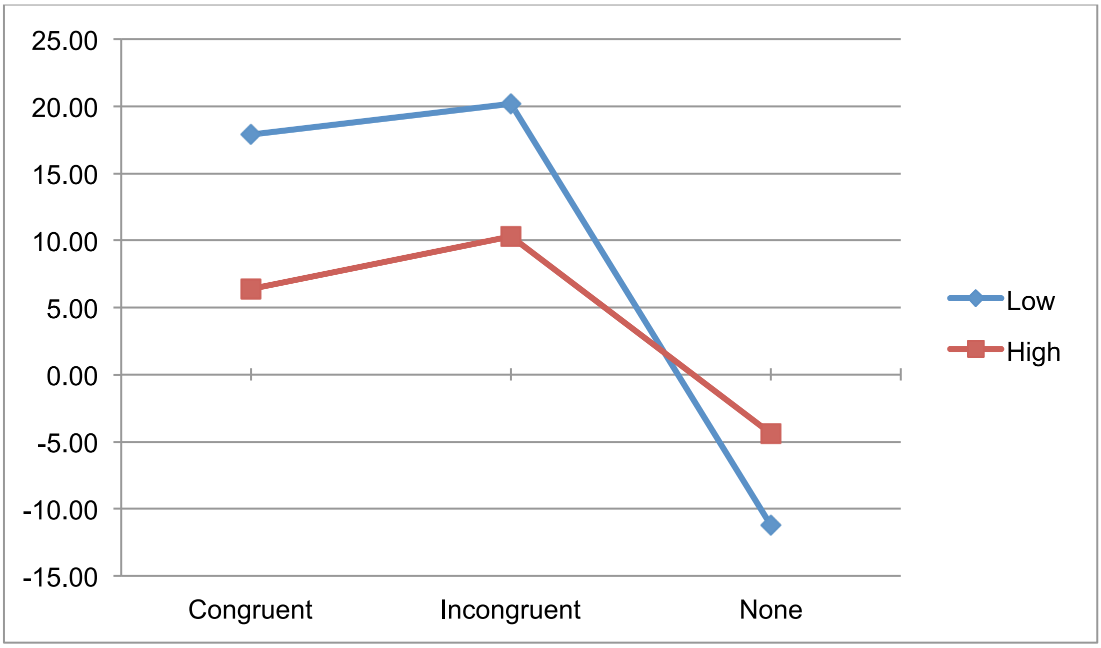
(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Primary Motor Cortex; 3 = S3 Frontal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each advice condition overlaid (congruent = red; incongruent = blue; none = green). Empty rectangles indicate statistically significant ($p < .05$) increase for source amplitudes in the no-advice conditions, while filled rectangles indicate statistically significant ($p < .05$) decrease for source amplitudes in the no-advice ones. Numbers of source waveforms correspond to (A).



Interaction between Consequence and Advice

A factorial repeated-measures ANOVA was carried out, with results pointing to significant effects of the consequence and advice conditions for two separate intervals recorded at the source dipole located in frontal lobe (S3). For the first time interval (-340ms to -250ms) Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of advice, $\chi^2 = 7.974$, $p = .019$, so therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .67$. The results showed no significant differences between the consequence conditions, but they did so for the advice conditions, F (1.346, 17.503) = 15.651, $p = .000$, when ignoring the scenario conditions. Contrasts revealed that this main effect reflected significant differences in activity the no-advice condition (M = -7.81, SE = 6.44) had when compared with the congruent, (M = 12.136, SE = 6.05), F (1, 13) = 17.439, p = .001, and incongruent, (M = 15.255, SE = 5.27), F (1, 13) = 17.478, p = .001, ones (see *Figure 4*).

Figure 4. Interaction graph for the mean activity recorded for the advice conditions in both consequence scenarios near the frontal lobe prior to making a choice (-340ms to -250ms)

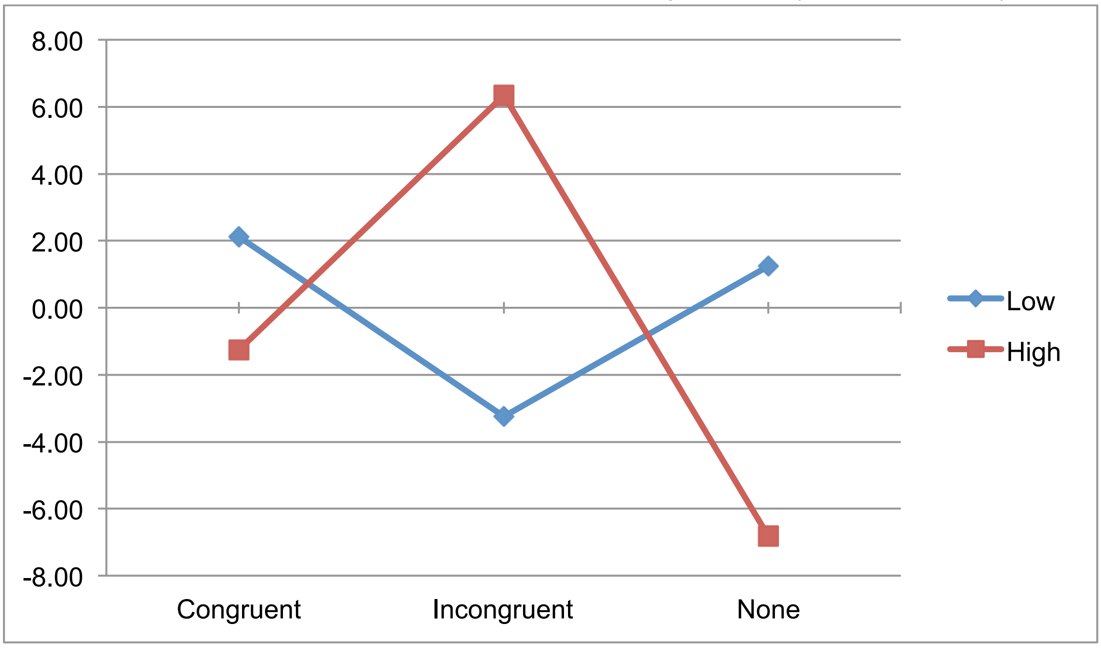


A significant interaction was observed between the type of advice and the scenario in which it was received, F (2, 26) = 5.413, p = .011. This showed that the consequence scenario had different effects on activity depending on which type of advice was available. The break-down for this interaction showed that there was a significant difference between the activity recorded for the low (M = 17.87, SD = 22.32) and high (M = 6.4, SD = 24.5) congruent conditions, t (13) = 3.553, p = .004. Similarly, recordings for the incongruent advice showed significant differences between the low (M = 20.2, SD = 20.55) and high (M = 10.31, SD = 21.16) consequence conditions, t (13) = 2.701, p = .018. This significant difference was not observed for the no-advice condition.

Further analysis showed significant differences between the advice conditions in the low-consequence scenarios, F (2, 26) = 17.545, p = .000. Contrasts showed that recordings for the no-advice condition (M = -11.23, SD = 29.92) were significantly lower than those for the congruent (M = 17.88, SD = 22.32), F (1, 13) = 20.798, p = .001, and incongruent (M = 20.2, SD = 20.55), F (1, 13) = 18.432, p = .001, ones. Analysis between the advice conditions in the high-consequence scenarios also showed significant differences, F (2, 26) = 4.812, p = .028. Similarly, these showed that recordings for the no-advice condition (M = -4.39, SD = 22.55) were significantly lower than those for the incongruent (M = 10.31, SD = 21.16), F (1, 13) = 6.51, p = .024, ones.

Analysis for the later interval (290ms to 350ms) at the same source dipole (S3) showed that there were no significant differences when considering the scenario or advice condition individually (see *Figure 5*). But a clear interaction was observed between the type of advice and the scenario condition in which it was received, F (2, 26) = 4.67, p = .019.

Figure 5. Interaction graph for the mean activity recorded for the advice conditions in both consequence scenarios near the frontal lobe after making a choice (290ms to 350ms)



The break-down again showed that the type of advice had a different effect on activity depending on which scenario condition is was presented in. Contrasts showed that a significant effect was only observed for the high-consequence scenarios, *F* (1, 13) = 6.691, *p* = .023, where the no-advice condition (*M* = -6.82, *SD* = 38.03) resulted in a larger decrease in amplitude than the incongruent (*M* = 6.33, *SD* = 34.68) one.

3.3 Reaction Times

When analysing the reaction times recorded for both, consequence and advice conditions (see *Figure 6*), the advice conditions were associated with significant differences (*F* (2, 26) = 17.574, *p* = .000), but the scenario conditions were not associated with significant differences (*F* (1, 13) = 0.687, *p* = .422) and there was no significant interaction between the two independent variables (*F* (4, 76) = 2.562, *p* = .096). Looking at the significant differences for the low-consequence scenarios (*F* (2, 26) = 20.589, *p* = .000) recordings showed significantly faster response times following congruent advice (*M* = 852.889, *SD* = 165.103), when compared to the incongruent (*M* = 1039.095, *SD* = 238.083), *F* (1, 13) = 41.564, *p* =

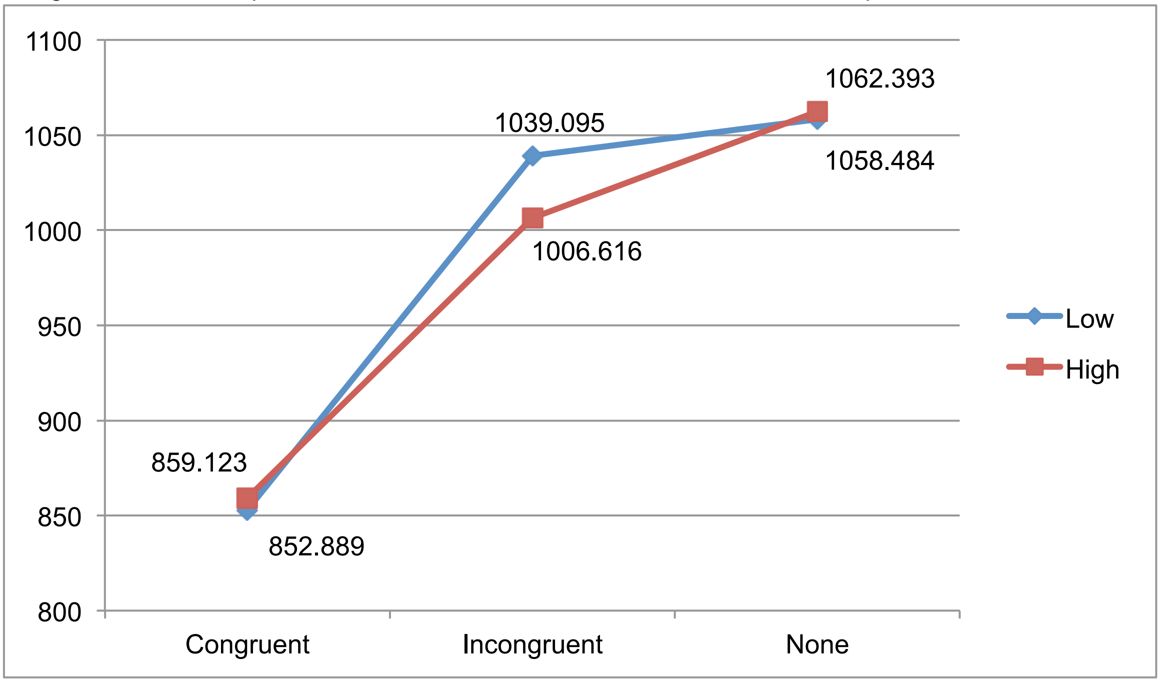
.000, $r = 0.87$, and no advice ($M = 1058.484$, $SD = 186.924$), $F\ (1, 13) = 31.768$, $p =$ .000, $r = 0.84$, conditions.

Table 7. Mean (SD) response times for each advice condition for both consequence levels

Consequence Scenario	*Stroop Advice*		
	Congruent	Incongruent	None
Low	852.889 (165.103)	1039.095 (238.083)	1058.484 (186.924)
High	859.123 (167.128)	1006.616 (225.183)	1062.393 (207.743)

Similarly, results for the high-consequence scenarios pointed to significant differences ($F\ (2, 26) = 13.558$, $p = .000$), with significantly faster response times after congruent advice ($M = 859.123$, $SD = 167.128$), when compared to incongruent ($M = 1006.616$, $SD = 225.183$), $F\ (1, 13) = 22.829$, $p = .000$, $r = 0.8$, and no advice ($M = 1062.393$, $SD = 207.743$), $F\ (1, 13) = 21.116$, $p = .001$, $r = 0.77$, conditions.

Figure 6. Mean response times for the advice conditions in both consequence scenarios



3.4 Qualitative Data

After completing the decision paradigm, participants filled out a post-task questionnaire (see *Appendix D*). These responses provide a qualitative insight into the decision-making processes and individuals' experience during the experiment.

They provided an overall narrative, to compliment the findings from the neurocognitive analysis.

When asked about how confident they felt about solving the task (Q.1), participants stated that they felt somewhat confident (Avg. 6 on a scale of 1-10), but that this confidence decreased over time ("*the task seemed easy at the beginning, but turned out to be quite hard.*"). Related to this, when asked about the strategy used to solve the task (Q.2), individuals stated that this as well changed over time ("*I tried remembering what the correct solution was in a particular scenario, which didn't work. I tried a sequential method, this time is blue next time red etc which didn't work.*").

In terms of their main concern (Q.3), participants stated that they did not feel any particular preference between the scenario conditions, as they were mainly focused on making the right choice ("*I felt concerned all the time, Not only during the more emotional scenarios.*" and "*I tried to get every answer right, and got frustrated in the end when I got them wrong.*"). While reflecting on their decisiveness and if they reconsidered their choice at the very last moment (Q.4), participants stated that they spent longer on the no-advice conditions, re-assessing and deliberating their choice ("*...sometimes I did the last second decisions, as I wasn't completely sure which option to choose...*" and "*Sometimes, because I was using the time to think it through from the last response.*").

In relation to the limited time available and the need to be accurate (Q.5), participants stated that the short time window added psychological pressure to the task, but that their main focus was still to try and be accurate in their decisions ("*I was more concerned with accuracy for the clips that were designed to be emotive.*" and "*At the start of each experiment I was a little nervous so I was definitely concerned about both time and accuracy but as the experiment progressed I felt more pressured into getting the questions right.*"). Finally, when asked if they would have benefitted from more time in order to solve the task (Q.6), participants stated that once they settled into the task, time was not an issue, while they still struggled with being accurate in their decisions ("*Once I was settled time was not an issue...*"

and "*I didn't think I could work out any rules to work out which wires to cut, so more time wouldn't have made any difference.*").

When asked about the perceived solvability of the task (Q.7), participants stated that there was no solution, supported by their assessment after trying out various strategies and successful ones being incorrect at later iterations of the task ("*I didn't think it was solvable, as I tried a few different techniques to work it out, but didn't get any further.*"). Further confirming this position, none of the participants claimed having found the correct solution (Q.8), while further describing the failure of applied strategies as time progressed ("*At first I thought something like red wire for a bomb and blue wire for the bell, but in the end I didn't think there was a solution and it was 50/50.*"). Despite these responses, participants stated that they still felt pressured throughout the task (Q.9), based on the regular feedback and the overall instructions of the experiment.

4. DISCUSSION

When considering the results from the experiment along the individual decision-making stages, it was clear that the different types of information provided as advice and the scenarios in which these were presented, had a varying effect on individuals' cognitive activity and their behavioural response when completing the task. Looking at the different types of advice, it was clear that the information-processing was different in terms of activation, which was further carried over into the implementation stage, significantly affecting the behavioural responses. These were identified at sources related to movement components, while differences were also observed at sources active during executive functioning. Further differences were also observed during all stages for vision-related sources, in terms of strength and length activation, which did not always fulfil expectations, raising some important issues about the experiments' design. Nonetheless, some key observations were drawn from these, informing propositions about the different consequence scenarios and the varying types of advice.

In order to further expand on these findings, the focus is first on the basic visual and cognitive processing at the initial stage, where individuals received contextual information about the operational scenario. The second part describes the advice presented in order to inform the task, looking at the response to each of the three conditions. Finally, we describe the processes leading to the implementation of a choice, and how these were mapped based on the information available, and discuss the extent to which it was possible to link the EEG results to our behavioural and qualitative measures.

4.1 Context Information

Analysis pointed to significant differences between the two scenario-consequence conditions, in terms of the effect the contextual stimuli had on visual processing. At the most fundamental level, the images used to represent both operational conditions differ in terms of complexity and visual information, thus variations in processing within the occipital lobe were expected. As the results showed, the high-consequence scenarios resulted in stronger and prolonged activation for all three source dipoles located in the occipital lobe. Further, some participants stated that as part of their strategy, they actively searched for clues in the scenarios, in order to inform their decisions, which would point the prolonged activation for the more complex scenario images.

While these shortcomings are not directly relevant to decision-making processing and only provide insight into the visual processing of contextual information, they do not undermine conclusions drawn from activity recorded in other brain areas. In the decision paradigm, the main goal was not to identify differences in processing based on visual stimuli, but to see if, how and at which interval this contextual information affected activity in other areas of the brain. The images merely served as a contextual trigger for individuals to visualize themselves operating in that particular situation, whether this meant solving the task in a low-consequence environment or a high-consequence one.

4.2 Advice Information

In terms of activity relating to the presentation of task-relevant information, included as advice or the lack-of it during the decision paradigm, the analysis looked again at the effect the scenario conditions had on this processing, but further included comparisons between the three types of advice. It is here where the established Reverse Stroop Test literature provided a strong basis to look at the differences between the proposed decision-making stages.

Scenario

Analyses showed that significant differences were only observed in the sources located in the occipital lobe, and that these differences were not consistent across all three advice conditions. As highlighted previously, the activity relating to visual processing of these conditions was not without flaw, in terms of any meaningful conclusions that could be drawn from them. In this stage, visually there was no difference between the scenarios, so any differences in the recordings were most likely due to unrelated visual activity. Further, the large standard deviations and the early time interval pointed to further weaknesses with the differences between the recordings at those sources.

Advice

When comparing the effect the three different types of advice had on brain activity, results for both lateral sources located in the occipital lobe pointed to larger amplitudes for the no-advice condition. Both of these amplitudes correspond to the N100 visually evoked potential, pointing to selective attention relating to the no-advice condition (Luck, Woodman, & Vogel, 2000), where those stimuli resulted in stronger activation due to the participants additional focus. This follows on from the idea around those ERP components (P1, N1) initially reflecting sensory processing of incoming information (Heinze, Mangun, Burchert, Hinrichs, Scholz, Münte, & et al., 1994), but further being strongly influenced by higher cognitive processes (Johannes, Münte, Heinze, & Mangun, 1995; Mangun, 1995).

Activity located in the contralateral temporal lobe (S4) showed that the no-advice condition resulted in larger amplitudes at both intervals (100ms to 190ms, and 280ms to 350ms) in the low-consequence conditions, while only being significantly different in the early one for the high-consequence one. The source localisation pointed to activity near Wernicke’s area, angular gyrus and the superior temporal gyrus, both active during understanding of spoken and written language (Luce & Pisoni, 1998; Geschwind, 2004). Expectations would point to stronger activation for both advice conditions where information was presented in written form, requiring more cognitive processing, while the opposite was observed. This pointed to possible activation due to the no-advice setting, drawing on other information recall. It was not possible to draw any definitive conclusions from the analysis at this particular source.

Similarly, activity recorded in the ipsilateral inferior temporal lobe (S6) did not correspond to expectations for the experimental paradigm. Analysis pointed to larger amplitudes for the no-advice condition at a very early interval (90ms to

200ms), while this shifted significantly to the other two advice conditions for the later interval (250ms to 350ms). Considering the pattern of activation and the localisation of the source, these recorded differences most likely related to the ventral stream (Milner & Goodale, 2008) and its description of similar visual processing as observed for one of the lateral occipital sources (S3). While propositions about this activation are still being debated (Cardoso-Leite & Gorea, 2010), they do provide the best explanation for the activation observed in this area, as it related to the visual processing of the advice information.

Finally, for the source located in the anterior cingulate cortex (S5), results showed that the congruent and incongruent advice condition resulted in larger amplitudes for an early interval (180ms to 280ms) than the no-advice one when presented during the high-consequence scenarios. This pointed to attention towards meaningful information, as identified for this brain area in previous research using the Stroop Test (Strauss, Sherman, & Spreen, 2006; Carter & van Veen, 2007). Incidentally, in this experiment only the high-consequence condition showed a significant difference and at an early interval, which goes against the most traditional descriptions of the conflict monitoring and resolution identified in the Stroop Test literature (Botvinick, Cohen, & Carter, 2004). Expectations would have pointed to similar differences for both scenario conditions, seeing as there was no interaction observed at this stage, as the task would be independent from the situational setting. None of the usual ERPs were observed in terms of Stroop interference (N/P450 and Sustained Potential), which reflect conflict processing and attentional control (Lansbergen, van Hell, & Kenemans, 2007), while no activation was observed at the dorsolateral prefrontal cortex (DLPFC) (Ukai, Shinosaki, Ishii, & et al., 2002).

Despite some differences in activation when compared to the available literature, the recordings still pointed to the expected variations when processing meaningful information (in both its congruent and incongruent forms) and the conditions where no information was available. The importance of these differences is best assessed in the processing of this information and its application when making a choice in the particular decision paradigm.

4.3 Decision-related components

The phase of most interest, in terms of identifying particular decision making stages, was the one just prior to the button press, as individuals deliberated about the available, or lack of, information and their commitment to implementing the particular choice. Similar as above, it was important to look at the different conditions individually, before drawing conclusions on the effect they had on their cognitive processing.

Significant differences were observed only in the source located in the occipital lobe, for the congruent and incongruent advice conditions. Again, there were no particular differences between the scenarios at this stage based on visual information. Considering the early activation, especially when overlaid with the response times, this activity most probably related to the presentation of the advice stimuli, and was unrelated to the actual decision-making process.

Considering visual processing, differences were again observed for the source located in the occipital lobe, where the congruent and incongruent conditions resulted in significantly larger amplitudes than the no-advice one. This related directly to the first two including some written information, while the other condition was blank and prompted individuals to shift focus directly to the consideration of their own solution strategy.

Interaction

Of particular interest was the possible interaction between the scenario and advice conditions, further exploring how these affected cognitive processing and which effect they on performance in the forced-choice decision paradigm. Analysis for the activity located in the frontal lobe (S3) showed two particular time intervals where an interaction was observed between the operational conditions.

When looking at the time prior to individuals making a choice (-340ms to -250ms) recordings showed that the congruent and incongruent advice condition resulted in a large positive amplitude in both consequence scenarios. On the other hand, the no-advice condition resulted in a large negative amplitude, but not significantly different when compared between the low- and high-consequence conditions. When considering activity in the same source after individuals' decision (290ms to 350ms), recordings showed that the type of advice had a significant effect on the high-consequence scenarios, but not on the low-consequence ones. While congruent advice did not affect activity, incongruent advice resulted in a large positive amplitude for the high-consequence condition. On the other hand, the no-advice conditions resulted in a large negative amplitude for the high-consequence ones.

The activity for the meaningful advice corresponded to activity in the dorsolateral prefontral cortex, recognised for its functional involvement in the Stroop Test (Vendrell, Junque, Pujol, Jurado, Molet, & Grafman, 1995; Stuss, Floden, Alexander, Levine, & Katz, 2001). Further, the DLPFC has been identified as playing a key role when solving ill-structured problems (Gilbert, Spengler, Simons, Steele, Lawrie, Frith, & Burgess, 2006), while also recent propositions have suggested that it is involved in strategic processes in memory retrieval and executive functions (Gilbert, Zamenopolous, Alexiou, & Johnson, 2010).

Considering the complex composition of this brain region, the results still provided some insight into the shift observed in terms of cognitive activity. Adding meaningful advice to the decision paradigm resulted in a shift in prioritisation during the task, especially when considering individuals' qualitative task description and the differences with Experiment 1. In this case, while consequence scenarios had an effect in the conditions where advice information was provided, it did not influence activity prior to the decision. On the other hand, the consequence conditions did affect activity in the same brain area after individuals made their choice, but only for the high-consequence scenarios resulting in significant differences. This pointed to a post-choice consideration, which was not observed for the low-consequence ones. Overall, the set-up of the decision-paradigm pointed to task-relevant information being more important than the consequential context at all stages, while it only seemed to affect activity after the decision was made.

While the current experiment focused on pre-decisional activity, some of the results pointed to future possibilities relating to post-decision measures. Some differences were observed in the figures for the recordings, with variations in the waveforms immediately after commission to a choice. Analysis in this area should look into possible activation describing feedback preparation and anticipated regret, while also considering potential issues relating to strategy consideration and re-assessment. While the current paradigm did not allow for any confident analysis in this phase, future research would benefit from measures around these areas, to further contribute to the decision-making narrative.

Response Times

In terms of the behavioural measures recorded, identifying activity relating to the stimuli presentation and choice response, results showed that individuals responded in the congruent advice conditions significantly faster than in the incongruent or no-advice ones. While the differences between the congruent and incongruent conditions do fall in line with the findings within the Stroop Test literature (MacLeod, 1991; Rosenfeld & Skogsberg, 2006), response times for the no-advice conditions were significantly longer for one. When looking at the cognitive measures in the no-advice conditions, they showed consistently early activation and differences in terms of shorter engagement in terms of perceptual processing. While no individual source of component stood out, these differences still raised the question why responses were still slower in those conditions, if no additional information was available.

The original expectation of slower response times for the incongruent and no-advice condition was fulfilled, but a subsequent comparison did not yield any clear conclusions. The original goal was to look at the cognitive processing for these two conditions, in order to identify activity relating to the processing of more effortful information (incongruent advice) or the application of problem-solving strategies in the absence of any information (no advice). One suggestion would describe similar response delay for both conditions, but no clear differentiation was possible with the current data. Ultimately, following on from earlier experiments, the aim was to identify redundant deliberation in forced-choice environments, as previously observed in situations when lacking any meaningful information. No brain regions were isolated individually for processing facing incongruent or no advice situations, which would have provided a basis on which to further differentiate between cognitive activities.

4.4 Experiment

This version of the experiment added a measure of solvability, through the inclusion of advice for the forced-choice decision paradigm, providing a framework on which to observe problem-solving processes. The solvability of the task was provided along a continuum, through varying degrees of difficulty, in order to further isolate differences in evaluation, deliberation and implementation stages. These variations, especially when compared to Experiment 1, were aimed at engaging the individual with the task, observing changes between the different approaches applied to process information, or the lack of, and the shift to implementation of a given choice.

While the behavioural responses did fulfil expectations about variations in information processing and response delay, insight gained through cognitive measures did not provide clear-enough frameworks on which to trace individual activation in particular time-intervals. Some of the problems were due to weak activation and variations in the analysis, which did not provide confident differentiation between the conditions. Nonetheless, the overall experimental design did allow for clear observation of individual decision-making stages, in order to identify the effect information processing had on responses.

5. CONCLUSION

The experiment showed how information is processed during forced-choice environments, as it affected response times based on its complexity, while the particular consequence conditions in which they were presented did not affect performance. Based on established findings of the Reverse Stroop Effect, a clear distinction was made between processing of clear information (congruent) and the delayed response when processing unclear information (incongruent) or when deliberating about a decision in the absence of information. The aim to confidently identify the distinct neurocognitive activity of complex information processing and redundant deliberation was not achieved, as the recordings and source localisation did not provide a clear difference. However, the results again pointed to distinct phases of processing, which fitted both the basic decision-making model and expectations in the response time variations.

Chapter VI

Advice Clarity

Experiment 5

1. INTRODUCTION

Based on the similar issues raised in Experiment 4 (see *Chapter V*), some questions remained in terms of the effect different types of information had on deliberation and implementation. This experiment looked at how unclear information is processed, and the raised demands it places on cognitive activity, in order for it to contribute to meaningful decisions. Further, this experiment also looked at how unclear information is recognised and ignored, opting for an individual solution to the task. Both of these conditions further helped in identifying the particular brain areas active during these processes, and how these choices were affected by the varying degrees of certainty at different levels of choice consequence. The experiment provided different types of advice, in the form of simple information on which to base the decision. Similar to the Stroop conditions described in the previous experiment, these variations were aimed at identifying variations in deliberation and implementation of decision, in combination with the findings on scenario conditions.

After looking at an artificial variation in task-advice (Stroop conditions), this experiment was aimed at looking at a more realistic presentation of advice and its effect on cognitive processing. In decision-making environments available advice is not always presented in a coherent manner. This can lead to additional cognitive demands on the decision maker, in terms of evaluating the relevance of such information for informing a current choice. With this in mind, and building on findings from the previous experiments, it was important to further identify how these variations in clarity and uncertainty of advice affected response times, and how these were reflected in terms of possible delay or effortful evaluation. It was shown in the previous experiments that the type of advice was significantly more influential on the decision maker than the situation in which it was presented. Therefore, it was important to look at how these variations reflected along a continuum when faced with a forced-choice, time pressured decision task in an experimental setting.

1.1 Information Uncertainty

The key focus in the experiment was on the uncertainty of information, which contributed to the ambiguity of task (Elliot, Dolan, & Frith, 2000). While advice within a task can be provided in different forms, it is also important to be able to differentiate this from superfluous or irrelevant advice, in order maximise its application and avoid processing meaningless information. In this experiment advice was provided on either a clear or more complex level. The experiment also included a condition utilising irrelevant advice which required the active effort of the decision maker to avoid it and use a personally held strategy to solve the task.

This combination of processes, identified in the prefrontal cortex, relates to the focus on externally presented information (stimuli), as in tasks of sustained attention (Kanwisher & Wojciulik, 2000), as well as the monitoring of internally held information, such as monitoring the content of episodic or working memory (Habib, Nyberg, & Tulving, 2003). The initial processing relates to the identification of incoming information, with a subsequent evaluation of its meaning. More complex information, incongruent or requiring an additional process of 'translation', probably directly affects cognitive processing and subsequent response.

On the highest level of uncertainty, unclear information requires significantly more effortful processing (Ward, 2010), an expectation incorporated into the experimental design. As information is identified, an evaluation about its validity needs to be completed, raising the activity relating to monitoring and attending

(Cabeza, Dolcos, Prince, Rice, Weissman, & Nyberg, 2003). Following this assessment, recognising the information as redundant and task-irrelevant, task-switching activity comes into play (Monsell, 2003). Task switching is the move from evaluation and deliberation in processing the available information, to the need to apply a different strategy to solve the task. On the most fundamental level, this would involve the deliberative retrieval from memory of the individual strategy (Mayr & Kleigl, 2000), based on alternative patterns and goals. But the goal in this experiment was to identify the *switch cost* (Wylie & Allport, 2000), as the difference between switch and non-switch tasks. This was then used as a means to differentiate between these two processes, relating to the cognitive activity observed when dealing with more complex information.

Considering the ambiguity of the task and the uncertainty of the outcome, based on the varying levels of meaningful advice information, it was essential to identify how these influenced response times and how this was reflected in cognitive activity. Similarly, the ability to differentiate between the processing of two complex types of information, each resulting in a switch towards a different problem-solving strategy, provided grounds to further confirm the role particular brain regions play during this type of decision making.

1.2 Objectives and Hypotheses

The aim of the experiment was to look at how cognitive processing and behavioural response during a simplified decision paradigm is affected by varying types of task-information as presented in different scenario conditions. Following on from previous findings around decision-making stages, the goal was to further assess the effect different levels of clarity had on information processing and how this was used to inform choices in a time-limited and performance-pressured environment. This experiment combined brain activity as well as behavioural data, to identify the time-intervals at which particular areas were most active and how this varied based on clarity of information and the consequence environment it was presented in. The following objectives were also considered:

> Identify the neural processes involved at each stage of decision making and map these out for each individual type of information.

> Emotional stimuli that suggest more significant and consequential outcomes will result in increased and prolonged amplitudes at the stages of deliberation, preparation and implementation.

> The incongruent and unclear information conditions will result in increased and prolonged amplitudes at the stages of deliberation and implementation with longer response times than the congruent information condition.

> The incongruent and unclear advice conditions will result in activation of different brain areas, providing a basis on which to differentiate between complex information processing (‘translation’) and task-specific problem solving (own strategy).

2. METHOD

2.1 Participants

Thirteen individuals (11 females, 2 males) participated in the experiment. They ranged in age from 19 to 33 years, with a mean age of 22 years. Participants were drawn from a sample of students at the University of Liverpool, all without any disclosed health issues, and were all right-handed.

2.2 Procedure

This experiment followed a similar set-up as previously discussed (see *Chapters II, III*, and *IV*), and closely mirrored conditions in Experiment 4. Participants were seated in a comfortable chair, inside a dimly-lit, electrically-shielded room, with their right arm resting on a platform. All task-related information was presented to them on a computer screen and they responded using a mouse placed below their right hand.

The experiment consisted of a series of decision situations, at the end of which individuals were asked to make a choice between two random alternatives under time pressure. The task consisted of a 'bomb scenario', where participants were asked to imagine themselves operating in the various situations with the objective to 'cut' a wire and disarm a bomb. Following this, they faced a decision stage and had to choose between two alternatives, in the form of two different-coloured wires (see *Table 1*) (failing to cut one of the wires quickly enough automatically led to 'detonation'). The basic premise of the decision problem focused on a binary negative outcome paradigm, where participants had to choose between two arbitrary alternatives, not knowing which would be the correct wire - reinforced through time constrains and performance pressures - and where a 'wrong' decision lead to a negative outcome.

Varying from the initial design, this experiment only focused on two situational settings. Participants were presented with a context-setting scenario involving either:

(i) a light-bulb, which they had to switch off by picking a wire (low consequence condition), or

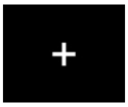
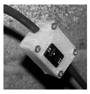
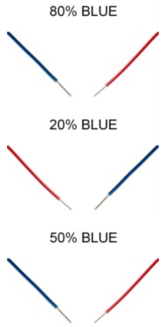
(ii) children on playground, in which the wires were used to disarm a bomb (high consequence condition).

In summary, the stimulus indicated two conditions: 1) low consequence, and 2) high consequence. This was followed by an image of a light switch (low consequence condition) or explosive device (high-consequence condition), to reinforce the situational context. Finally participants were prompted to choose between a red or blue wire 'connected' to the particular device. Failure to make a decision or a wrong one, led to detonation of the device. Following each choice, they received feedback in the form of a "*CORRECT*" or "*INCORRECT*" on-screen message.

The instructions, prior and during the experiment, all emphasised the need to take quick and decisive action. Participants were told that they would be assessed on their accuracy as well as their speed, forming part of an overall learning task. As part of this learning task, in some instances they received percentile 'advice' on the likelihood of which wire was the correct one (i.e. 80% BLUE or 20% BLUE), varying in the clarity of information provided. While in others they received unclear advice (i.e. 50% BLUE or 50% RED). This information was provided as a direct statement above the two wires. Following on from the design in Experiment 4 these variations represented congruent or incongruent conditions, while the unclear advice condition mirrored the no advice one, in terms of details available to inform one's choice.

A total of 240 stimuli series were presented in two blocks of 22 minutes each, with a 5 minutes break between them. The order in each block of 120 stimuli was randomised, combining both scenario conditions (i.e. low- and high-consequence) with all three advice conditions (i.e. congruent, incongruent, and unclear advice).

Table 1. Decision Paradigm (examples)

Stage		Evaluation	Deliberation	Choice	
Stimuli	Mask	Context	Device	Decision	Feedback
		 	 		CORRECT or INCORRECT or TOO SLOW
TIME	*2,000ms*	*2,000ms*	*2,000ms*	*3,000ms*	*1,500ms*

2.3 Recordings

EEG was recorded using 64 electrodes in continuous mode on Biosemi (ActiView v6.05, Amsterdam – Netherlands). A band pass filter of 0.16-100 Hz and a sampling rate of 500 Hz were used, while the electrode-to-skin impedance was kept below 5 kΩ. Elecrooculography (EOG) measures were recorded, using electrodes placed above and below the left eye, while electrocardiographic (ECG) measures were recorded by placing one electrode on the right ankle and another one on the left wrist. Both of these recordings were used to account for any artefacts in the data analysis.

The decision scenarios were designed using Inquisit (Millisecond Software v3.0.4, Seattle – USA), and recordings for each participant's response times were taken at each decision stage.

2.4 Data Analysis

Averaged EEG epochs were segmented after band pass filtering and analyzed using the Brain Electrical Source Analysis (BESA) program (MEGIS Software, Munich – Germany). Trials containing ECG artefacts or large EOG variations (> 75 mV) were discarded from further analysis. There were two vision-related measures, with one focusing on the presentation of scenario context stimuli and the other on the advice stimuli. For the scenario-related measures, 2,707 averaged EEG epochs were segmented to a length of 1,100 ms (100 ms pre- to 1, 000 ms post-stimulus), while for the advice-related measures, 3,015 averaged EEG epochs were segmented to a length of 800 ms (200 ms pre- to 600 ms post-stimulus). For the movement-related measures, 2,912 averaged EEG epochs were segmented to a length of 2,000 ms (1,500 ms pre- to 500 ms post-stimulus). A source model of the EEG potentials was constructed from the grand average data (N = 13) for each of the measures. The data was transformed into the Talairach coordinate system, and the locations of the EEG sources were evaluated for each individual dipole (Talairach Client v2.4.2, Research Imaging Centre, UTHSCSA - USA).

2.5 Statistical Analysis

The effect of stimulus intensity on the dipoles source was analysed using a t-test for the scenario conditions, comparing the recordings following stimuli presentations. The independent variables at this stage were the two different scenario conditions (low- and high-consequence). For the latter stages, advice presentation and choice commitment, the stimulus intensity on the dipoles source was analysed using a factorial repeated-measures analysis of variance (ANOVA). The independent variables for both included again the scenario conditions (high and low), and the three different types of advice (congruent, incongruent, and unclear).

3. RESULTS

The results will detail three stages for each decision task within the experiment, describing the differences in amplitudes for each of the source dipoles, directly following the presentation of stimuli or the commitment to a choice. First, the focus will be on the perception components relating to the presentation of the context-setting stimuli, indicating the scenario in which individuals were 'operating' in. Further, the focus will be on the perception components relating to the advice provision and, finally, on the activity prior to the button press and commitment to a choice. For all of these stages, the data will be compared based on the two consequence conditions, looking for significant difference in the source waveforms. Similarly, the second and third stages will further, additionally to the scenario conditions, consider the differences in advice provision, and any significant interaction. Additionally, behavioural and qualitative measures will be analysed, to further expand on the decision-making narrative.

3.1 Perception Components

3.1.1 Scenario Consequence

Five regional source dipoles were fitted to describe the 3-dimensional source currents contributing to the data (see *A,* in *Figure 1*). Three sources were located in the occipital lobe. The central source (S1, Talairach coordinates in mm [x: -1.4, y: -82, z: 2.2], Brodmann area 18) peaked at 103ms. Two secondary sources, occupying lateral locations ($S2_R$ [x: 39.5, y: -76.3, z: 0.5], 19/18, and $S3_L$ [x: -29.5, y: -91.3, z: -2.2], 18) peaked at 135ms and 94ms respectively. Another source was located in the posterior cingulate cortex (S4 [x: 9.7, y: -27.1, z: 37.8], 31), peaking at 92ms. While the last source was located in the frontal lobe (S5 [x: -8.6, y: 47.8, z: 13], 10) and peaked at 115ms. The grand-average model was tested for all conditions, and the residual variances were similar in both conditions (both 10%, low-consequence 15%, high-consequence 9%) (see *B*, in *Figure 1*).

To evaluate the differences between the two scenario conditions, individual source waveforms for each were obtained using the grand-average model. The average source waveforms with time intervals showing statistically significant deviation ($p < 0.05$) between the different conditions are shown in Figure 1.

Analysis showed that in three separate time intervals for the source located in the occipital lobe (S1) were associated with significant differences for the different scenario conditions. An early interval (120ms to 210ms) showed that the high-consequence scenarios resulted in a larger increase in amplitude than the low-consequence ones, $t = -3.9446$, $p = .000$. A second interval (570ms to 670ms) for the same source dipole showed a similar result, with the high-consequence scenarios resulting in a larger increase than the low-consequence ones, $t = -4.5488$, $p = .000$. The last interval (680ms to 780ms) in the same source showed that the high-consequence scenarios resulted in a larger increase in amplitude than did the low-consequence ones, $t = -4.227$, $p = .000$.

Significant differences were observed at both lateral sources dipoles ($S2_R$ & $S3_L$) located in the occipital lobe. An early interval (170ms to 360ms) in right source ($S2_R$) showed that the high-consequence scenarios resulted in a larger decrease in amplitude than the low-consequence ones, $t = 8.51$, $p = .000$. For the left source ($S3_L$), three separate time intervals were identified. An early interval (170ms to 260ms) showed that the high-consequence scenarios resulted in a larger increase in amplitude than the low-consequence ones, $t = -5.0028$, $p = .000$. A later (350ms to 450ms) similarly showed that the high-consequence scenarios resulted in a larger increase in amplitude when compared to the low-consequence ones, $t = -3.458$, $p = .000$. A last interval (480ms to 560ms) further showed that the high-consequence scenarios resulted in continued larger increase in amplitude than the low-consequence ones, $t = -4.1124$, $p = .000$.

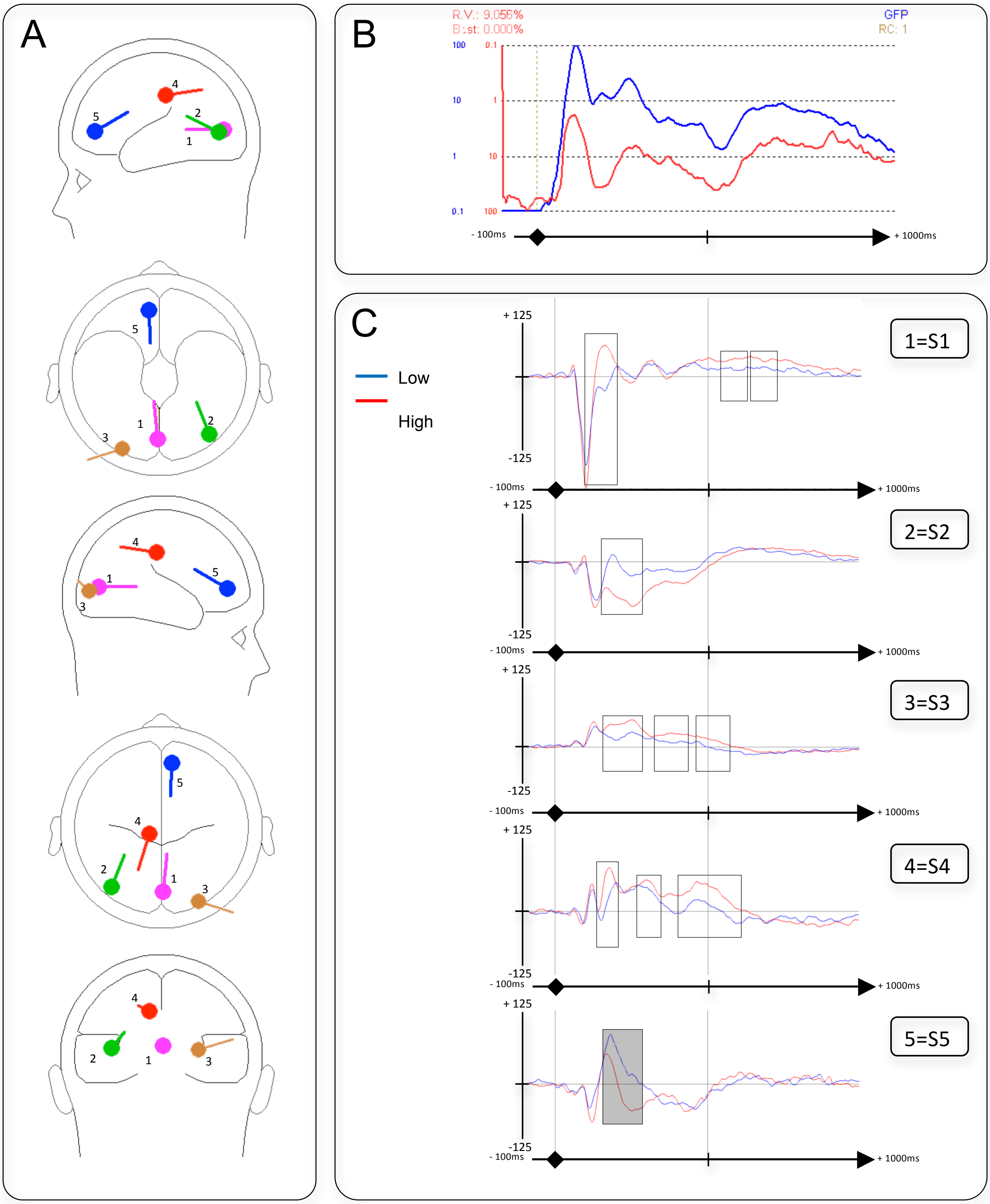
Table 2. Mean activity recorded for scenario-perception components with significant differences between consequence conditions

Source	*Consequence Scenario*		Analysis	
	Low	High	*t*	*p*
S1.1 (120ms – 210ms)	M = -10.63, SD = 17.25	M = 15.41, SD = 34.69	-3.9446	.000
S1.2 (570ms – 670ms)	M = 8.51, SD = 7.41	M = 20.25, SD = 11.39	-4.5488	.000
S1.3 (680ms – 780ms)	M = 8, SD = 7.1	M = 17.79, SD = 11.06	-4.227	.000
S2 (170ms – 360ms)	M = -8.02, SD = 15.68	M = -37.35, SD = 20.61	8.51	.000
S3.1 (170ms – 260ms)	M = 11.74, SD = 12.68	M = 26.52, SD = 9.99	-5.0028	.000
S3.2 (350ms – 450ms)	M = 5.27, SD = 6.99	M = 14.17, SD = 10.88	-3.458	.000
S3.3 (480ms – 560ms)	M = -1.5, SD = 8.19	M = 7.25, SD = 8.38	-4.1124	.000
S4.1 (130ms – 210ms)	M = 12.84, SD = 14.74	M = 28.83, SD = 17.98	-3.6536	.000
S4.2 (340ms – 430ms)	M = 2.52, SD = 18.41	M = 18.41, SD = 15.29	-5.6284	.000
S4.3 (440ms – 600ms)	M = 2.87, SD = 9.21	M = 21.81, SD = 13.4	-7.658	.000
S5 (180ms – 290ms)	M = 22.2, SD = 16.23	M = -13.46, SD = 22.33	6.1751	.000

Analysis for the source dipoles in the limbic lobe (cingulate gyrus) (S4) identified again three separate time intervals which showed significant results. An early interval (130ms to 210ms) showed that high-consequence scenarios resulted in a larger increase in amplitude than the low-consequence ones, t = -3.6536, p = .000. A later interval (340ms to 430ms) showed similar differences, with high-consequence scenarios resulting in a larger increase in amplitude when compared to low-consequence ones, t = -5.6284, p = .000. A following interval (440ms to 600ms) showed a prolonged difference, with high-consequence scenarios continue still resulting in larger amplitudes than the low-consequence ones, t = -7.658, p = .000.

A final difference was observed in the source located in the frontal lobe (S5). For this interval (180ms to 290ms) results showed that the low-consequence scenarios resulted in a larger increase in amplitude than the high-consequence ones, t = 6.1751, p = .000.

Figure 1. *Scenario Consequence Components*
(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Occipital Lobe; 3 = S3 Occipital Lobe; 4 = S4 Cingulate Cortex; 5 = S5 Frontal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each scenario conditions overlaid (low-consequence = blue; high-consequence = red). Empty rectangles indicate statistically significant (p < .05) increase for source amplitudes in more consequential scenario conditions, while filled rectangles indicate statistically significant (p < .05) decrease for source amplitudes in more consequential ones. Numbers of source waveforms correspond to (A).



3.1.2 Advice

For the advice perception-related components associated with the advice stimuli six regional source dipoles were fitted to describe the 3-dimensional source currents (see *A*, in *Figure 2.1*, *Figure 2.2*, and *Figure 2.3*). Again, three sources were located in the occipital lobe. The central source (S1 [x: 9.3, y: -79.3, z: 11.4], 17) peaked at 105ms. Two secondary sources, occupying lateral sources ($S2_L$ [x: -32.8, y: -84.3, z: -21.5], 18, and $S3_R$ [x: 14.2, y: -64.9, z: -6.9], 19/18) peaked at 244ms and 293ms respectively. A fourth source was located in the contralateral temporal lobe (S4 [x: -39.6, y: -34.6, z: 17.8], 41), peaking at 188ms. The fifth source was located in the anterior cingulate cortex (S5 [x: 7.0, y: 32.9, z: 14.4], 24), and peaked at 195ms. A last source was located in the ipsilateral temporal lobe (S6 [x: 35.6, y: 2.4, z: -26.3], 38), peaking at 246ms. The grand-average model was tested for all conditions, and the residual variances were similar in all low- (all 10%, congruent 10%, incongruent 10%, unclear advice 11%) as well as high-consequence advice conditions (all 13%, congruent 13%, incongruent 12%, unclear advice 12%) (see B, in *Figure 2.1*, *Figure 2.2*, and *Figure 2.3* respectively).

Following the same approach as the perception components above, the individual source waveforms for each advice condition in both consequence levels were obtained using the grand-average model, in order to evaluate the differences between them. The average source waveforms with time intervals showing statistically significant deviation ($p < 0.05$) between the different conditions are shown in Figure 2.1, Figure 2.2, and Figure 2.3.

Consequence

Analyses showed that a number of time intervals in various source dipoles resulted in significant results when comparing the recorded amplitudes for the two scenario conditions. For the congruent advice conditions, four source dipoles showed significant differences. The time interval (160ms to 260ms) located in the occipital lobe (S1) showed that the low-consequence scenarios resulted in a larger decrease of amplitude than the high-consequence ones, $t = -3.078$, $p = .010$. During a similar interval (180ms to 270ms) for the source located in the left occipital lobe ($S2_L$) recordings also showed that the low-consequence scenarios resulted in a larger decrease in amplitude when compare to the high-consequence ones, $t = -3.481$, $p = .005$.

For the congruent advice conditions, results also showed significant differences between the scenario conditions for the sources located in the anterior cingulate (S5) and ipsilateral temporal lobe (S6). The interval in the former one (170ms to 240ms) showed that the high-consequence conditions resulted in a larger increase in amplitude than the low-consequence ones, $t = -3.268$, $p = .007$. For the latter source, a similar interval (180ms to 260ms) showed also that the high-consequence scenarios resulted in a larger increase in amplitude than the low-consequence ones, $t = -2.711$, $p = .019$.

Table 3. Mean activity recorded of advice-perception components with significant differences between consequence conditions, for all types of advice

Advice	Source	*Consequence Scenario*		Analysis	
		Low	High	*t*	*p*
Congruent	S1 (160ms – 260ms)	M = -14.13, SD = 17.59	M = -9.44, SD = 17.32	-2.395	.032
	S2 (180ms – 270ms)	M = -9.53, SD = 13.28	M = -5.08, SD = 10.59	-3.448	.004
	S5 (170ms – 240ms)	M = 23.56, SD = 20.39	M = 32.6, SD = 18.78	-3.268	.007
	S6 (180ms – 260ms)	M = 16.8, SD = 19.85	M = 24.67, SD = 14.68	-2.711	.019
Incongruent	S1 (160ms – 260ms)	M = -9.87, SD = 24.08	M = 2.41, SD = 25.99	-5.546	.000
	S2 (180ms – 270ms)	M = 22.37, SD = 20.45	M = 30.86, SD = 25.96	-3.724	.003
Unclear	S1 (160ms – 260ms)	M = -9.01, SD = 26.94	M = -0.17, SD = 29.27	-2.628	.022
	S5 (170ms – 240ms)	M = 21.41, SD = 16.79	M = 31.44, SD = 15.71	-3.262	.007
	S6 (180ms – 260ms)	M = 14.66, SD = 17.08	M = 26.31, SD = 14.5	-3.701	.003

In the congruent advice condition, results showed significant differences for two of the sources located in occipital lobe. The one interval (S1, 160ms to 260ms) showed that the low-consequence condition resulted in a larger decrease in amplitude than the high-consequence one, $t = -5.546$, $p = .000$. On the other hand, the similar interval (180ms to 270ms) at the lateral source ($S2_L$) showed that the high-consequence scenario resulted in a larger increase in amplitude than the low-consequence one, $t = -3.724$, $p = .003$.

Finally, for the no-advice conditions, three separate sources showed significant differences between the two scenario conditions. For the source located in the occipital lobe (S1) an early time interval (160ms to 260ms) showed that the low-consequence scenario resulted in a larger decrease in amplitude than the high-consequence one, $t = -2.628$, $p = .022$. The other two sources showed similar differences, in terms of localisation and time interval, as those observed for the congruent advice condition. The interval (170ms to 240ms) for the source located in the anterior cingulate (S5) showed that the high-consequence scenario resulted in a larger increase in amplitude than the low-consequence one, $t = -3.262$, $p = .007$. Similarly, the time interval (180ms to 260ms) located in the ipsilateral temporal lobe (S6) showed that the high-consequence scenarios resulted in a larger increase in amplitude than the low-consequence ones, $t = -3.701$, $p = .003$.

Advice

When looking for the significant differences between the three advice conditions as presented for each of the scenario conditions, analysis showed that there were no significant differences between them.

Interaction between Consequence and Advice

Further analysis showed that there was no significant interaction between the type of advice given and the scenario conditions in which they were received, when looking at the recorded activity before and after the presentation of the wires.

Figure 2.1. Difference between the consequence scenario conditions for the advice-perception components when presented with congruent advice

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Occipital Lobe; 3 = S3 Occipital Lobe; 4 = S4 Temporal Lobe; 5 = S5 Cingulate Cortex; 6 = S6 Temporal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each scenario conditions overlaid (low-consequence = blue; high-consequence = red). Empty rectangles indicate statistically significant ($p < .05$) increase for source amplitudes in more consequential scenario conditions, while filled rectangles indicate statistically significant ($p < .05$) decrease for source amplitudes in more consequential ones. Numbers of source waveforms correspond to (A).

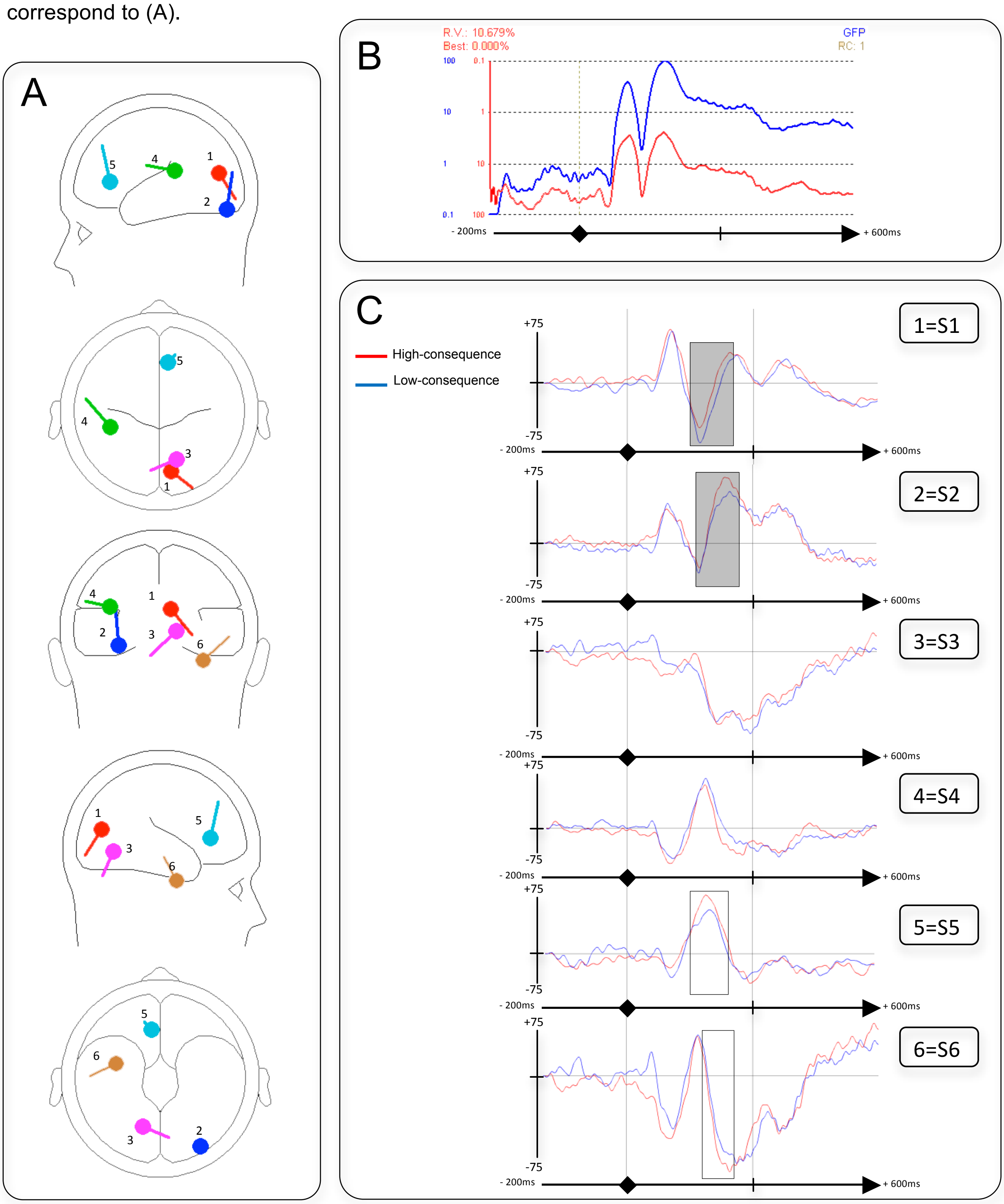


Figure 2.2. Difference between the consequence scenario conditions for the advice-perception components when presented with incongruent advice

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Occipital Lobe; 3 = S3 Occipital Lobe; 4 = S4 Temporal Lobe; 5 = S5 Cingulate Cortex; 6 = S6 Temporal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each scenario conditions overlaid (low-consequence = blue; high-consequence = red). Empty rectangles indicate statistically significant ($p < .05$) increase for source amplitudes in more consequential scenario conditions, while filled rectangles indicate statistically significant ($p < .05$) decrease for source amplitudes in more consequential ones. Numbers of source waveforms correspond to (A).

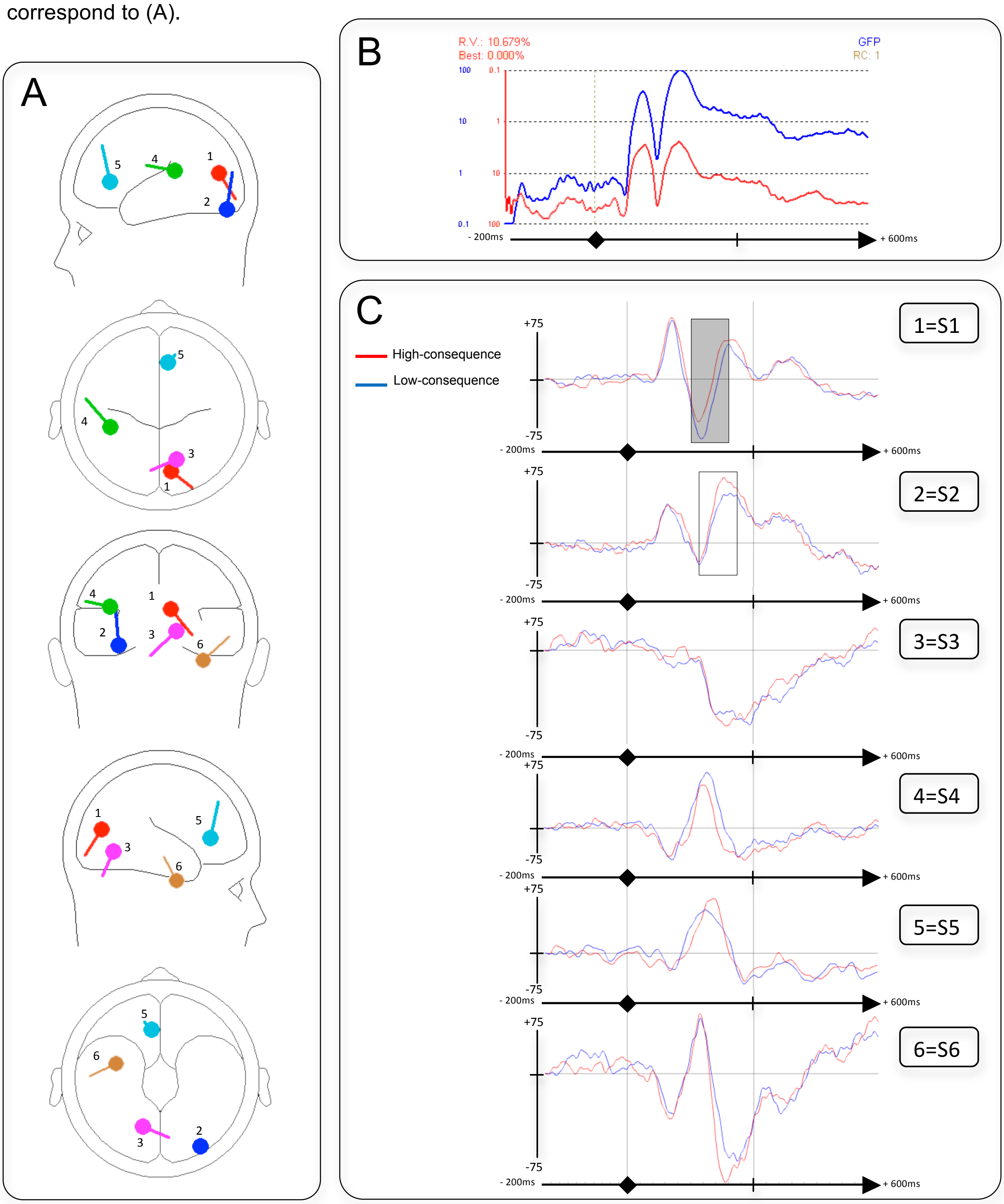
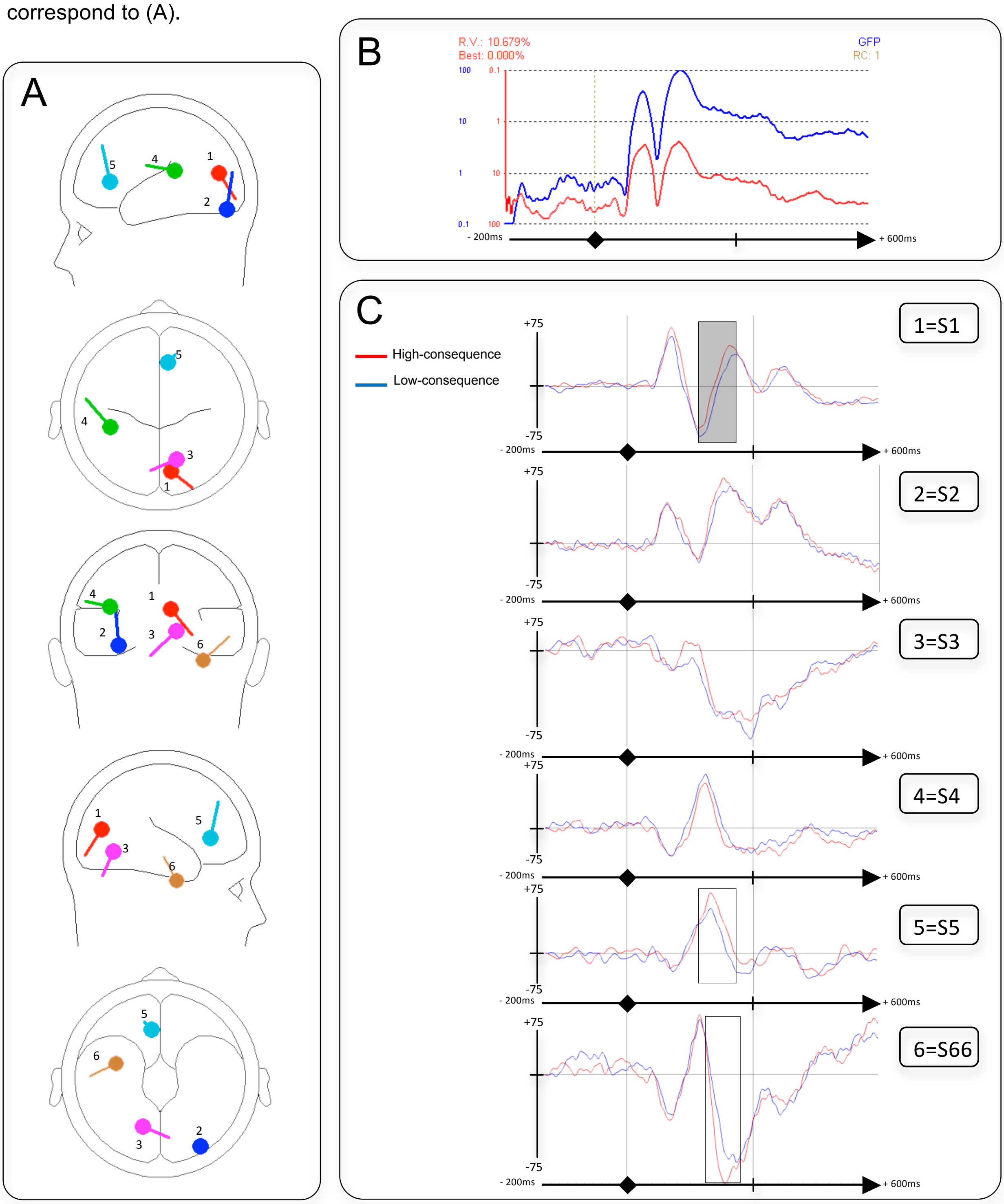


Figure 2.3. Difference between the consequence scenario conditions for the advice-perception components when presented with unclear advice

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Occipital Lobe; 3 = S3 Occipital Lobe; 4 = S4 Temporal Lobe; 5 = S5 Cingulate Cortex; 6 = S6 Temporal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each scenario conditions overlaid (low-consequence = blue; high-consequence = red). Empty rectangles indicate statistically significant ($p < .05$) increase for source amplitudes in more consequential scenario conditions, while filled rectangles indicate statistically significant ($p < .05$) decrease for source amplitudes in more consequential ones. Numbers of source waveforms correspond to (A).



3.2 Decision Components

Movement-related: Choice

For the last part of the analysis relating to the EEG recordings, four regional source dipoles were fitted to describe the source currents (see *A*, in *Figure 3.1* and *Figure 3.2*). One source was located in the occipital lobe (S1 [x: 17, y: -60.4, z: -3.1], 19), peaking at -1,000ms. The second source was located in the anterior cingulate cortex (S2 [x: 10.3, y: -0.4, z: 35.2], 24) and peaked at -55ms. The third source was located in the contralateral primary motor cortex (S3 [x: -27.1, y: -23.2, z: 59.6], 4) and peaked at -6ms. The final source was located in the frontal lobe (S4 [x: -17, y: 50.8, z: 23.3], 10), peaking at -850ms. The grand-average model was tested for all conditions, and the residual variances were similar in all low- (all 32%, congruent 30%, incongruent 30%, unclear advice 35%) as well as high-consequence advice conditions (all 35%, congruent 38%, incongruent 30%, unclear advice 36%) (see B, in *Figure 3.1* and *Figure 3.2* respectively).

To evaluate the differences between the three advice conditions for both consequence levels, individual source waveforms for each were obtained using the grand average model. The average source waveforms with time intervals showing statistically significant deviation ($p < 0.05$) between the different conditions are show in Figure 3. Analysis of the selected Bereitschaftspotential parameters was performed, using a three-way ANOVA for repeated measures at both low- and high-consequence scenarios, factoring in all three advice types. The focus was on particular time intervals, prior to the participants' voluntary movements, identifying their commitment to a particular choice through movement-related potentials (see *C*, in *Figures 3.1* and *Figure 3.2* respectively).

Consequence

The analysis for the last component focused on the processes leading up to the commission of a decision, describing the activity from deliberation to choice. Results showed that there were a number of source dipoles where the scenario conditions resulted in significant differences at various time intervals for each of the different types of advice.

In the congruent advice condition, results showed a prolonged period where the scenario conditions resulted in a significant effect on the activity recorded for the source located in the occipital lobe (S1). Over three almost-continuous time intervals (S1.2: -730ms to -650ms, S1.3: -620ms to -520ms, and S1.4: -510ms to -370ms) recordings showed that the low-consequence conditions resulted in a larger increase in amplitude when compared to the high-consequence ones, $t = 2.944$, $p = .012$, $t = 3.291$, $p = .006$, and $t = 4.02$, $p = .002$. A time interval closer the button press (-300ms to -190ms) in the same location showed that the low-consequence condition still resulted in a larger increase in amplitude than the high-consequence one, $t = 3.11$, $p = .009$.

For the same congruent advice condition, two further differences were recorded at different intervals for the source dipole located in the frontal lobe (S4). An early interval (-1200ms to -1080ms) showed that the low-consequence scenario resulted in a lager increase in amplitude than the high-consequence one, $t = 2.298$, $p = .04$. Similarly, a later interval (-720ms to -620ms) showed a similar difference between the two scenario conditions, $t = 4.740$, $p = .000$.

Table 4. Mean activity recorded for movement components with significant differences between consequence conditions, for all types of advice

Advice	Source	*Consequence Scenarios*		Analysis	
		Low	High	*t*	*p*
Congruent	S1.2 (-730ms – -650ms)	M = 25.69, SD = 37.3	M = 11.94, SD = 31.39	2.944	.012
	S1.3 (-620ms – -520ms)	M = 31.7, SD = 35.57	M = 13.96, SD = 36.98	3.291	.006
	S1.4 (-510ms – -370ms)	M = 29.16, SD = 35.25	M = 12.19, SD = 31.27	4.02	.002
	S1.5 (-300ms – -190ms)	M = 15.65, SD = 35.81	M = 0.03, SD = 28.06	3.11	.009
	S4.1 (-1200ms – -1080ms)	M = 6.69, SD = 8.68	M = 0.19, SD = 9.48	2.298	.04
	S4.2 (-720ms – -620ms)	M = 20.23, SD = 17.3	M = 3.07, SD = 13.47	4.74	.000
Incongruent	S1.1 (-870ms – -790ms)	M = 19.92, SD = 27.36	M = 5.32, SD = 19.92	3.133	.009
	S1.2 (-730ms – -650ms)	M = 20.07, SD = 28.77	M = 4.56, SD = 23.08	4.114	.001
	S1.4 (-510ms – -370ms)	M = 3.58, SD = 31.35	M = -11.61, SD = 25.94	5.297	.000
	S1.5 (-300ms – -190ms)	M = -9.55, SD = 31.31	M = -23.66, SD = 25.33	3.263	.007
Unclear	S1.1 (-870ms – -790ms)	M = 16.49, SD = 28.67	M = 0.63, SD = 24.65	2.331	.038
	S4.1 (-1200ms – -1080ms)	M = 9.12, SD = 9.11	M = -2.14, SD = 12.43	2.875	.014

For the incongruent advice condition, results pointed to significant difference between the scenario conditions only for the source located in the occipital lobe (S1). Two early time intervals (S1.1: -870ms to -790ms, and S1.2: -730ms to -650ms) both showed that the low-consequence conditions resulted in a larger increase in amplitude than the high-consequence ones, t = 3.133, p = .009, and, t = 4.114, p = .001. On the other hand, when looking at two later intervals nearer the button press (S1.4: -510ms to -370ms, and S1.5: -300ms to -190ms), recordings showed that the high-consequence conditions resulted in a larger decrease in amplitude when compared to the low-consequence ones, t = 5.297, p = .000, and, t = 3.263, p = .007.

Finally, recordings for the conditions where the advice was unclear showed that significant differences between the scenario conditions were observed at two source dipoles. An early interval (-870ms to -790ms) for the source dipole located in the occipital lobe (S1) showed that the low-consequence condition resulted in a larger increase in amplitude than the high-consequence one, t = 2.331, p = .038. For the source located in the frontal lobe (S4) analysis for an early interval (-1200ms to -1080ms) showed again that the low-consequence condition resulted in a larger increase in amplitude when compared to the high-consequence one, t = 2.875, p = .014.

Advice

Further analysis was carried out separately for both scenario conditions, to look at significant difference between different types of advice. When looking at the low-consequence scenarios, advice conditions were associated with statistically significant differences in a number of source dipoles. Recordings for the source dipole located in the occipital lobe (S1) showed that differences between the types of advice were observed for a number of time intervals. A difference was observed for an early interval (-550ms to -400ms), F (2, 24) = 9.030, p = .001, which showed a larger increase in amplitude for the congruent advice condition, a significant decrease for the incongruent advice condition, and finally a negative increase for the unclear advice one.

A later interval (-350ms to -200ms) in the same source showed that a difference between the types of advice still persisted, F (2, 24) = 8.200, p = .002. But contrasts revealed that the congruent advice condition resulted in significant larger increase in amplitude when compared to the incongruent, F (1, 12) = 11.923, p = .005, and unclear advice, F (1, 12) = 9.402, p = .01, ones. Differences were still observed for the interval just prior to the button press (-170ms to -40ms), F (2, 24) = 16.943, p = .000, where the congruent advice resulted in a larger increase in amplitude than the incongruent one, F (1, 12) = 27.375, p = .000, and the unclear advice one resulted in a significant negative increase, F (1, 12) = 25.627, p = .000. In the interval just following the button press (40ms to 130ms) the significant difference, F (2, 24) = 4.134, p = .029, was observed for the larger increase in amplitude when choosing based on congruent advice when compared to the unclear advice, F (1, 12) = 5.927, p = .031.

For the source located in the limbic lobe (S2) one time interval (-700ms to -600ms) showed significant differences between the types of advice available, F (2,

24) = 10.359, p = .001. Contrasts revealed that the incongruent, F (1, 12) = 23.322, p = .000, and unclear advice, F (1, 12) = 19.997, p = .001, resulted in a larger increase in amplitude when compared to the congruent advice condition.

Recordings for the source dipole located in the frontal lobe (S4) revealed three separate time intervals with significant differences between the advice conditions. Differences for the interval prior to the button press (-760ms to -680ms), F (2, 24) = 3.702, p = .04, showed that the unclear advice resulted in a larger increase in amplitude when compared to the incongruent one, F (1, 12) = 6.292, p = .027. When looking at the interval just after the button press (50ms to 130ms), F (2, 24) = 6.27, p = .006, contrasts revealed that the congruent advice resulted in a larger decrease in amplitude than the unclear advice, F (1, 12) = 8.952, p = .011. A later interval after the button press (350ms to 470ms) pointed to further differences, F (2, 24) = 8.741, p = .001, where the unclear advice resulted in a larger increase in amplitude when compared to the congruent, F (1, 12) = 10.963, p = .006, and incongruent, F (1, 12) = 18.787, p = .001, ones.

Table 5. Mean activity recorded for movement components with significant differences between advice conditions, for both consequence scenario conditions

Consequence Scenario	Source	*Advice*			Analysis	
		Congruent	Incongruent	Unclear	*F* (2, 24)	*p*
Low	S1.1 (-550ms – -400ms)	M = 29.84, SD = 35.11	M = 5.86, SD = 30.41	M = -8.08, SD = 24.56	9.030	.001
	S1.2 (-350ms – -200ms)	M = 17.08, SD = 36.08	M = 5.86, SD = 30.41	M = -15.5, SD = 26.83	8.200	.002
	S1.3 (-170ms to -40ms)	M = 15.75, SD = 28.85	M = -8.77, SD = 29.23	M = -17.77, SD = 35.48	16.943	.000
	S1.4 (40ms – 130ms)	M = 11.34, SD = 28.71	M = 10.03, SD = 31.66 *	M = -4.86, SD = 34.07	4.134	.029
	S2.1 (-700ms – -600ms)	M = 7.74, SD = 21.5	M = 27.05, SD = 27.3	M = 26.56, SD = 20.4	10.359	.001
	S3.1 (-760ms – -680ms)	M = 0.47, SD = 17.23 *	M = 4.74, SD = 21.52	M = -6.27, SD = 10.86	3.702	.04
	S3.2 (50ms – 130ms)	M = -15.04, SD = 18.06	M = -7.63, SD = 15.74 *	M = -2.38, SD = 20.81	6.27	.006
	S3.3 (350ms – 470ms)	M = 0.9, SD = 19.06	M = 1.88, SD = 18.23	M = 12.8, SD = 18.28	8.741	.001
High	S1.1 (-550ms – -400ms)	M = 12.74, SD = 31.71	M = -7.97, SD = 23.97	M = -15.48, SD = 26.34	6.517	.005
	S1.2 (-350ms – -200ms)	M = 2.5, SD = 28.15	M = -22.26, SD = 25.82	M = -18.51, SD = 30.27	5.386	.012
	S1.3 (-170ms – -40ms)	M = 1.01, SD = 29.36	M = -18.2, SD = 30.11	M = -16.68, SD = 35.13	5.345	.012
	S1.4 (40ms – 130ms)	M = 11.86, SD = 30.39	M = -1.7, SD = 27.27	M = -5.86, SD = 35.76	7.100	.004
	S3.1 (-760ms – -680ms)	M = 5.24, SD = 18.43 *	M = 11.92, SD = 25.88	M = -2.45, SD = 14.42	4.178	.028
	S3.2 (50ms – 130ms)	M = -12.42, SD = 16.63	M = -5.05, SD = 19.53 *	M = -2.64, SD = 20.58	4.24	.026
	S3.3 (350ms – 470ms)	M = 3.65, SD = 15.27	M = 2.71, SD = 25.27	M = 13.59, SD = 16.72	4.628	.02

** No significant differences were observed for those recordings when compared to the other conditions.*

For the high-consequence conditions, the source dipoles located in the occipital lobe (S1) and in the frontal lobe (S3) showed intervals of significant difference between the types of advice presented. An early interval (-550ms to -400ms) in the occipital lobe showed significant differences, F (2, 24) = 6.517, p = .005, where the incongruent, F (1, 12) = 4.917, p = .047, and unclear advice, F (1, 12) = 9.809, p = .009, resulted in a larger increase in amplitude when compared to the congruent advice condition. For a later interval (-350ms to -200ms) in the same source, F (2, 24) = 5.386, p = .012, the differences pointed to the continuing trend, where the incongruent, F (1, 12) = 9.314, p = .01, and unclear advice conditions, F

(1, 12) = 4.908, *p* = .047, resulted in a larger increase in amplitude than the congruent one.

Recordings at the same source dipole (S1) for the interval just prior to the button press (-170ms to -40ms), the differences showed, F (2, 24) = 5.345, p = .012, that the incongruent, F (1, 12) = 11.609, p = .005, and unclear advice conditions, F (1, 12) = 5.154, p = .042, resulted in a larger increase in amplitude when compared to the congruent advice one. On the other hand, differences in the interval just after the button press (40ms to 130ms), F (2, 24) = 7.100, p = .004, showed that the congruent advice condition resulted in a larger increase in amplitude than the incongruent, F (1, 12) = 15.354, p = .002, and unclear advice, F (1, 12) = 9.623, p = .009, ones.

Analysis for the source dipole located in the frontal lobe (S3) revealed three separate time intervals with significant differences between the types of advice, similar to those observed for the low-consequence scenario condition. Differences in the early interval prior to the button press (-760ms to -680ms), F (2, 24) = 4.178, p = .028, showed that the incongruent advice conditions resulted in a larger increase in amplitude than the unclear advice ones, F (1, 12) = 7.118, p = .02. When looking at the interval just after the button press (50ms to 130ms), F (2, 24) = 4.24, p = .026, contrasts revealed that the congruent advice resulted in a larger decrease in amplitude than the unclear advice, F (1, 12) = 5.927, p = .031. A later interval after the button press (350ms to 470ms) pointed to further differences, F (2, 24) = 4.628, p = .02, where the unclear advice resulted in a larger increase in amplitude when compared to the congruent, F (1, 12) = 9.92, p = .008, and incongruent, F (1, 12) = 6.596, p = .025, ones.

Interaction between Consequence and Advice

Analysis for the movement-related decision components showed that there was no significant interaction between the type of advice given and the scenario conditions in which they were received, when looking at the recorded activity before and after the presentation of the wires.

Figure 3.1 Difference between the advice conditions for the movement components when presented in the low-consequence scenarios

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Cingulate Cortex; 3 = S3 Primary Motor Cortex; 4 = S4 Frontal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each advice condition overlaid (congruent = red; incongruent = blue; no-advice = green). Empty rectangles indicate statistically significant ($p < .05$) increase for source amplitudes in the no-advice conditions, while filled rectangles indicate statistically significant ($p < .05$) decrease for source amplitudes in the no-advice ones. Numbers of source waveforms correspond to (A).

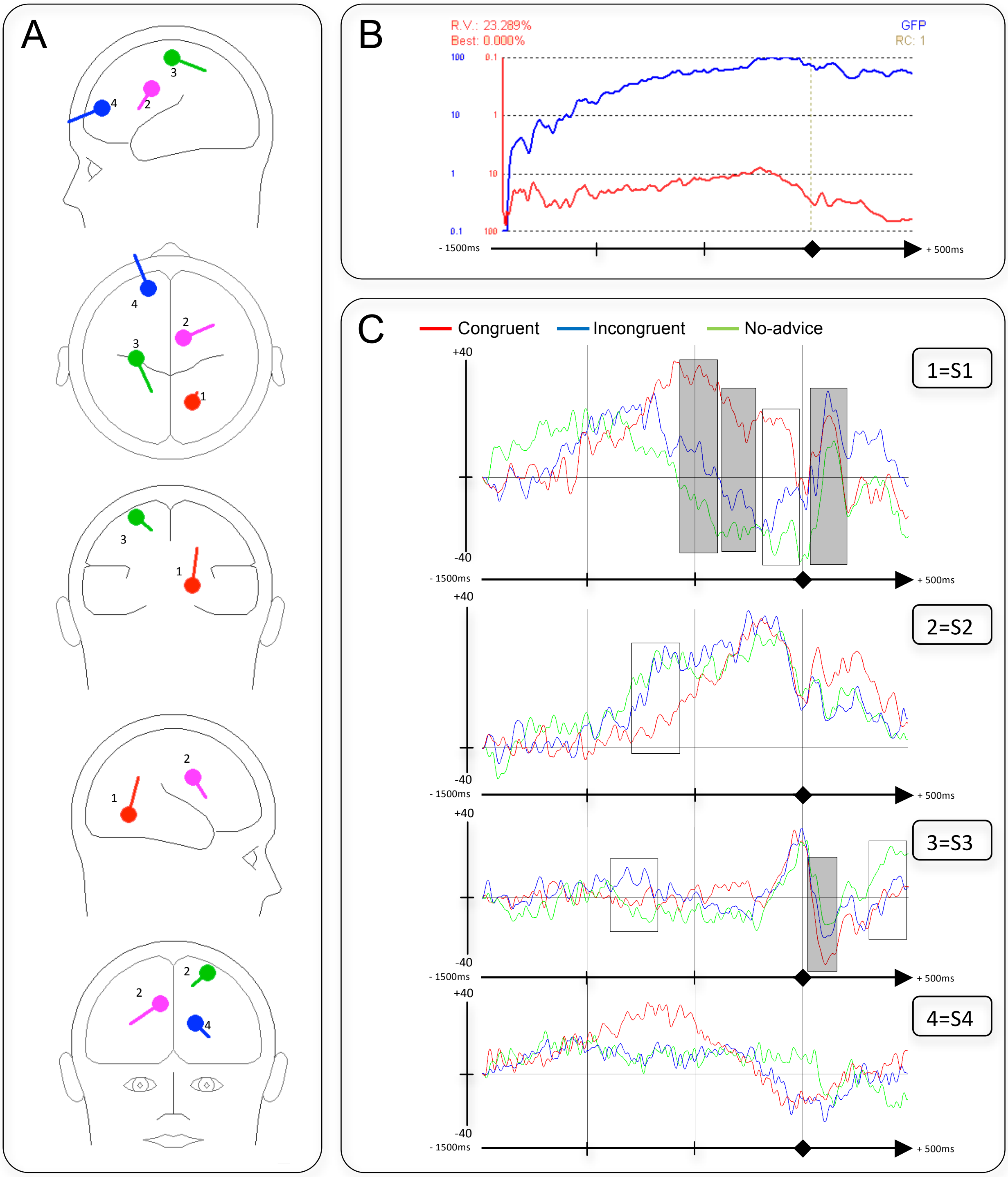
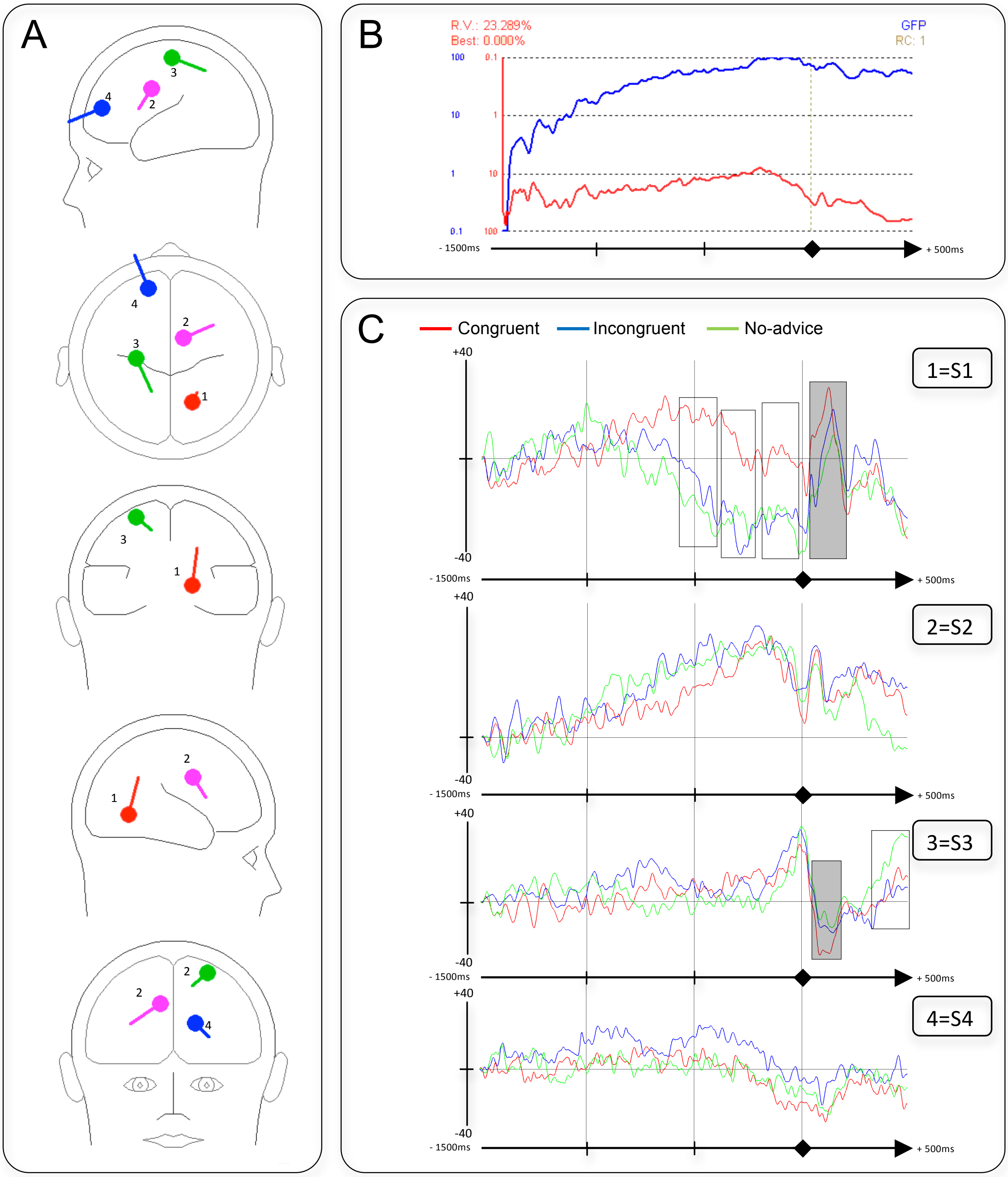


Figure 3.2 Difference between the advice conditions for the movement components when presented in the high-consequence scenarios

(A) Localisation of source dipoles shown schematically in the transparent glass brain. Short lines in each source indicate the orientation of the primary component of the respective regional source. Source labels: 1 = S1 Occipital Lobe; 2 = S2 Cingulate Cortex; 3 = S3 Primary Motor Cortex; 4 = S4 Frontal Lobe. (B) Global field power (blue scale) and residual variance (red scale). (C) Source waveforms of source dipoles derived from the grand average data. Averages for each advice condition overlaid (congruent = red; incongruent = blue; no-advice = green Empty rectangles indicate statistically significant (p < .05) increase for source amplitudes in the no-advice conditions, while filled rectangles indicate statistically significant (p < .05) decrease for source amplitudes in the no-advice ones. Numbers of source waveforms correspond to (A).



3.3 Reaction Times

Analysis of the reaction times showed that the advice conditions were associated with significant differences (F (1.176, 14.109) = 16.396, p = .001), while the scenarios conditions did not show any significant differences (F (1, 12) = 0.149, p = .707). There was no significant interaction between both independent variables (F (2, 24) = 2.232, p = .129). Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of advice, χ^2 (2) = 13.283, p = .001. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .588).

When looking at the significant difference for the low-consequence scenarios (F (1.276, 15.308) = 20.560, p = .000), tests again showed that the assumption of sphericity had been violated for the main effect of advice, χ^2 (2) = 9.227, p = .01; thus, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .638). Recordings showed a significant increase in response times following congruent advice (M = 1034.629, SD = 175.677), when compared to incongruent advice conditions (M = 1229.242, SD = 226.007), F (1, 12) = 40.709, p = .000, r = 0.88, and a further significant increase when looking at unclear advice conditions (M = 1414.665, SD = 229.684), F (1, 12) = 7.993, p = .015, r = 0.63.

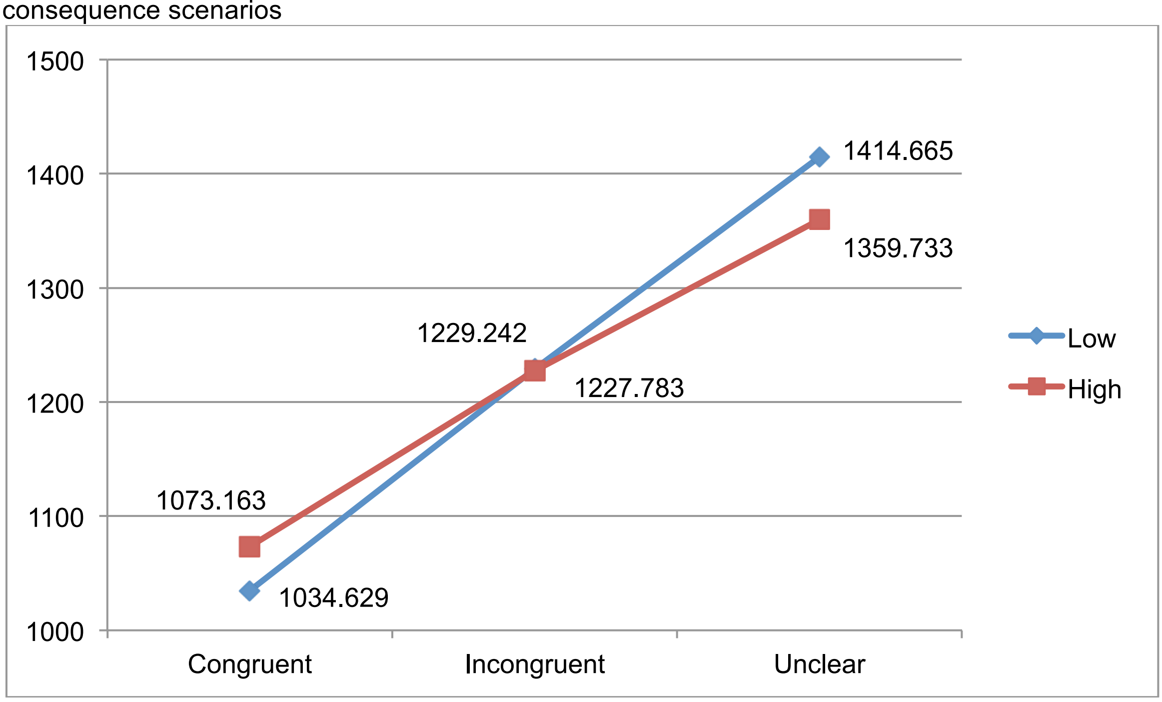
Table 6. Mean (SD) response times for each advice condition for both consequence levels

Consequence Scenario	*Advice*		
	Congruent	Incongruent	Unclear
Low	1034.629 (175.677)	1229.242 (226.007)	1414.665 (229.684)
High	1073.163 (206.175)	1227.783 (218.186)	1359.733 (221.772)

Similarly, the assumption of sphericity was violated for the main effect advice in the high-consequence scenarios, χ^2 (2) = 14.272, p = .001, therefore correcting again the degrees of freedom using Greenhouse-Geisser estimates of sphericity (ε = .579). Results for the high-consequence scenarios pointed to significant differences (F (1.158, 13.899) = 9.675, p = .006), with a significant increase in response time after congruent advice (M = 1073.163, SD = 206.175), when compared to incongruent advice conditions (M = 1227.783, SD = 218.186), F (1, 12) = 28.400, p = .000, r =

0.84, and a further increase when compared to the unclear advice ones (M = 1359.733, SD = 221.772), F (1, 12) = 11.694, p = .005, r = 0.7.

Figure 4. Interaction graph for the mean response time for the advice conditions in both consequence scenarios



The results for the differences in reaction times were overlaid with the significant differences in amplitudes observed for the movement-related sources (see *Figure 4*).

3.4 Qualitative Data

After completing the decision paradigm, participants filled out a post-task questionnaire (see *Appendix D*). These responses provide a qualitative insight into the decision-making processes and individuals' experience during the experiment. They provided an overall narrative, to compliment the findings from the neurocognitive analysis.

When asked about how confident they felt about solving the task (Q.1), participants stated that they felt quite confident (Avg. 7 on a scale of 1-10) in their ability, even if they did not find a pattern to solve it ("*I felt confident about my logical ability to find patterns, then that quickly diminished as I was never seeing a pattern arise.*"). When asked about particular strategies (Q.2), individuals described various attempts, which reflected a prolonged search effort to find a solution ("*I felt patterns occurring and would try and follow them. Then they would change and I would try and follow the new pattern.*").

In terms of their main concern and feelings of anxiety (Q.3), individuals did not state any particular preference for any particular scenario, as they were focused on making the right choice ("*Consciously I didn't as I was too focused on trying not to blink and working out the pattern.*"). When asked about their decisiveness and any last-moment doubts about their decision (Q.4), participants said that they occasionally found themselves re-considering their choice, especially following repeated mistakes in previous decisions ("*Sometimes yes, because a few incorrect answers made me to rethink the strategy I used before with correct answers.*").

There was an overall split between those seeing time or accuracy as their main concern (Q.5), while most agreed that time was a driver at the beginning until they settled into the task and tried solving the pattern ("*The time was an issue at the start as it did not sound very long and I felt this would cause problems in my accuracy, but actually the time was fine so I would say accuracy was my main focus.*"). In relation, when asked if more time would have allowed them to solve the task (Q.6), the majority stated that it would not have made a difference, as the changing pattern involved renewed effort to figure out a strategy ("*Because it seemed that there was more than one strategy one could use so more time would not help.*").

Most participants stated that they perceived the task as not being solvable (Q.7), due to the changing pattern and level of difficulty ("*No, it was very difficult. In fact I still think it was a random choice.*"). When further asked about if they had figured out a possible solution (Q.8), they continued to point to the insolvability ("*No, it was very difficult. In fact I still think it was a random choice.*"). Nonetheless, despite the difficulty of the task, participants still felt pressured to be fast as well as accurate (Q.9), as a combination of their feeling of frustration and the negative feedback ("*Because I had done badly in the first section I wanted to do better in the second section.*").

4. DISCUSSION

The results from this experiment were consistent with previous findings, further lending support to the propositions around the individual decision-making stages identified through the particular decision paradigm. Each of the three advice conditions – congruent, incongruent and unclear – resulted in significantly different response times, while activity leading up to the response showed particular differences of this in various brain regions. The scenario conditions, similar to previous experiments, did not play a significant role when looking at the overall decision-making process, as attention shifted to the available advice. In terms of the advice, the observed differences were in line with expectations, but the results did not provide sufficient ground on which to draw distinct activation maps between both more complex information conditions.

When exploring these findings in more detail, the focus will first be on the recordings for the initial perception components, describing the scenario and advice presentation. The processes leading up to the implementation will be described next, identifying the cognitive activity corresponding to each condition and how it was reflected in the behavioural response in each decision. These measures were considered to map out how factors regarding available information and scenarios lay, and how these corresponded to the behavioural and qualitative measures.

4.1 Context Information

While the analysis pointed to significant differences between the two scenario conditions, these were mostly observed in the brain regions corresponding to visual processing. Relating again to the experiment design, these particular differences needed to be considered in terms of the complexity of the images used, rather than the contextual information they represented. Identifying activity located in the occipital lobe the high-consequence scenarios resulted in stronger and prolonged activation, which reflected the expected variations based on stimuli characteristics. This activity cannot be directly accredited to the operational conditions, and were limited in terms of basic visual-processing differences between the images. These shortcomings were not directly related to the decision-making process, as the images served as a contextual trigger to place individuals in the particular operational situations. So the significant differences, despite those also observed in the posterior cingulate cortex and the frontal lobe, could not be confidently related to activation due to the low- or high-consequence environments as such.

4.2 Advice Information

For activity relating to the presentation of task-relevant information, as advice given when faced with the choice between the two wires, the analysis looked again at the effect the scenario conditions had on this processing, but further included comparisons between the three types of advice.

Scenario

Some differences were observed for the sources located in the occipital lobe at very early time intervals, but they were not consistent across all three advice conditions. Visually, there were no differences between the scenarios, and as highlighted above, drawing direct conclusion from any differences in visual processing was not without flaws. Similarly, although some differences were observed for the other two sources, these again were not consistent for all types of advice. Overall, as findings indicated in previous experiments, individuals did not show any particular difference at this stage in terms of processing relating to the contextual situation they were receiving the advice in. While activation in the limbic lobe would point to differences between the scenario consequences (Nieuwenhuys, Voogd, & van Huijzen, 2008), findings did not allow for the clear differentiation, due to the early activation and large standard deviations. Further, no additional stimuli relating to the scenarios was provided at this stage, so any conclusions drawn would relate to the prolonged activation relating to the previous stimuli.

Advice

When comparing the effect the three types of advice had on brain activity at this stage, results showed that there was no difference between them for any of the scenario conditions. In terms of visual processing, no differences were expected, seeing as all stimuli contained similar written information, without any variation in terms of basic characteristics. Based on the experimental premise, there were expectations regarding activity for the different types of advice, with stronger activation in the prefrontal cortex as well as temporal lobe (Kanwisher & Wojciulik, 2000; Habib, Nyberg, & Tulving, 2003); neither of which was observed in this experiment.

One explanation for this relates to the short time window analysed, which looked at the immediate response after stimuli presentation. While visual processing is completed early, more complex processes would occur only after the information had been processed. In the current set-up, these late activations would already fall within the range of individuals' response times, and thus overlap and be directly observed as decision-related components. This would be further compressed, considering the repetition and habituation effect of the task. With this in mind, it was best to look at the activity directly preceding individuals' choice, to get a better understanding of any possible differences based on advice or the scenarios in which it was received.

4.3 Decision-related components

The key phase identified in the decision paradigm which corresponded to the decision-making processes was the one just prior to individuals pressing the mouse button, as they deliberated about the available information and their commitment to implementing a particular choice.

Significant differences were observed between the scenario conditions, mainly in the source located in the occipital lobe (S1). These differences, at various time intervals, were observed for all three advice conditions. As highlighted above, this activity was prolonged and related to the presentation of the stimuli, considering the overlap it had when considering the average response times. At the same time, differences were also observed in the source located in the frontal lobe (S4), where the low-consequence scenarios resulted in stronger activation for the congruent and unclear advice conditions. These differences were not consistent across the types of advice, and were observed at early time intervals (1200ms-1000ms and 720ms-620ms before button press), just after the presentation of the advice stimuli. This pointed again to an overlap with the perception-related activity, relating to the evaluation phase, rather than the deliberation and implementation phases. Seeing as there were no clear differences between the scenario conditions, and no clear conclusions were drawn about the activity following the presentation of that stimuli, it was again difficult to confidently draw any conclusions about the differences observed prior to individuals' choice.

When looking at the way individuals processed the advice they received, results showed significant differences in a number of sources in the brain. For both, low- and high-consequence conditions, recordings for the source located in the occipital lobe showed a prolonged positive amplitude for the congruent advice, compared to a prolonged negative amplitude for the incongruent and unclear advice. When considering the basic characteristics of the stimuli, there was no reason to expect any significant difference in terms of visual processing, seeing as all three types of advice consisted of very similar written information.

For the source located in the anterior cingulate cortex, results showed a significant difference in activity, where the incongruent and unclear advice resulted in an earlier and larger increase in activity, when compared to the congruent advice. This pointed to higher attentional effort required to process that type of advice (Posner & Petersen, 1990). Incongruent advice required additional 'translation' of information before it could be used in a meaningful way to solve the task at hand. The unclear advice required similar processing, while it possibly served more as a cue to switch to an individual problem-solving strategy (Monsell, 2003). Based on predictions, we expected to see also a significant difference between these two conditions, as each required a different cognitive process. This was not the case in this experimental set-up, but possible reasons for this related to the limitations of the measures taken, relating to the precise localisation.

Directly describing individuals' preparation to press the button, activity in the contralateral primary motor cortex pointed to differences between the advice conditions. This activity corresponded to the organisation of the motor cortex and enabled the monitoring of movement (Coles, 1989), which showed that congruent and incongruent advice resulted in an earlier activation than the unclear advice. Especially when comparing both more effortful advice conditions, results showed that the unclear advice reflected a stronger readiness potential (Coles, Gratton, Bashore, Eriksen, & Donchin, 1985; Coles, Gratton, & Donchin, 1988; De Jong, Wierda, Mulder, & Mulder, 1988), with a later increase than the other two conditions. The incongruent advice, on the other hand, resulted in an early positive amplitude, and a sustained activation and increase prior to making a choice. While individuals were ready to move ahead into an implementation of their choice when they received some type of advice, when processing their own strategy, activation was delayed and movement-related activity reflected a stronger readiness potential. While the differences are within a narrow time-frame, when compared with the differences in response times, they do suggest again an insight into the differences in cognitive processing on a cognitive level.

Response Times

The behavioural measures recorded, describing the time it took individuals to process the advice information, deliberate about it and reach a decision on which wire to cut, showed a significant increase from the congruent, to the incongruent and finally the unclear advice condition, for both of the consequence scenarios. Individuals made significantly faster decisions when presented with clear advice, while it took them longer to make a choice when they had to translate the advice first. This was in line with the cognitive measures taken, showing prolonged activity for the more complex advice, resulting in a delay in response.

Similarly, when being presented with unclear advice, participants needed to process that cue and then apply their own strategy, which resulted in longer response times. This delay corresponded individuals' task descriptions, where they would try different solution patterns and needed to re-frame their strategy following an incorrect choice. While the cognitive measures did not provide sufficient grounds on which to explain the differences in response times between the two more complex advice conditions, the overall trend in increase delay was in line with expectations.

4.4 Experiment Design

While the decision paradigm continued to provide insight into different processes at the different stages of decision-making, it did not allow for the confident identification of distinct source activation relating to the advice processing. The use of EEG for this goal was limited by the spatial resolution of the source dipoles, making it unable to isolate processing relating to each of the individual types of advice. The expectations about differences in terms of response were present, but any conclusions were limited. Nonetheless, the temporal resolution allowed for the clear differentiation in terms of activation, duration and change of the evoked potentials; prior to and following the stimuli at the individual decision-making stages.

5. CONCLUSION

The experiment showed how cognitive processing and behavioural responses were influenced by varying levels of clarity of information. While there was a clear difference in both, delay in response time as well as activation in brain regions corresponding to this choice implementation, there was no clear distinction in terms of complex information processing and individual strategy implementation. Again issues were raised regarding the confidence of localisation possible with EEG measurements. It was not possible to definitively point to variations between these fundamentally different processes, but the results did point to the need to look in more detail into how information complexity results in delay, as described through the neurocognitive measurements available.

Chapter VII

General Discussion

An insight into thoughts about actions

The thesis set out to look at how information is received (input), processed (deliberation) and used to make a choice (output) in forced-choice and time-constrained situations. Considering the various factors that cause individuals to delay decision-making, the two explored in this research relate to (1) the potential emotional consequence of making an incorrect choice, and (2) engaging in redundant deliberation when lacking meaningful task-related information. Furthermore, this was set out in an experimental framework, incorporating insights from a neurological level, with the goal of advancing our understanding of the validity of mapping unique processes within particular regions of the brain. These measures, in addition to behavioural, quantitative and qualitative descriptions, provided a more in-depth insight into how information and environmental conditions affect cognitive processing in experimental forced-choice situations.

This chapter provides a general discussion of the main findings and implications of this study. Before outlining the conclusions and contributions of the thesis, it is important to provide a brief summary of the results, for both neurocognitive and behavioural measures, based on the various iterations of the forced-choice paradigm utilised. This follows the experimental development, aimed at identifying individual stages around the evaluation of information, the deliberation of alternatives and the implementation of a choice (Gollwitzer, Heckhausen, & Steller, 1990).

1. Summary of Results

The first experiment (Chapter II) provided bases on which to frame basic decision-making processes, in order to isolate and identify distinct brain activation. Findings showed that emotion, as influenced by task conditions, has an effect on neurocognitive processing during decision-making. The scenarios with lower negative outcomes resulted in stronger and more prolonged activation for components describing the preparation prior to and implementation of a decision. More surprisingly, results showed that individuals engaged in redundant deliberation within those situations where meaningful information was unavailable. This deliberation yielded differences in response times between the scenario conditions, where individuals responded slower during those scenarios with less consequential outcomes. However, rationally, in none of the decision-making tasks information was available on which to base one's judgement or choice preference. Finally, the findings from this initial study raised some questions about the decision paradigm's design and effect on participants' performance, which were addressed in the next two experiments.

Questions about the effect of feedback on response times were addressed in the second experiment (Chapter III), by examining heightened or lowered sense of confidence as a possible mediating variable for the variations found in response times. Repeated positive or negative feedback on individuals' decisions did not show to have an effect on their response times during this particular decision paradigm. Moreover, the results between the scenario conditions were similar to those in the first experiment, with faster responses found during the more consequential scenarios than the less consequential ones. This reiterated the important role that the operational conditions played during the decision task, where individuals were influenced by the environmental conditions irrespective of their confidence perceptions.

Another question raised related to the effect information loading had on cognitive processing and response times. The results showed that individuals were engaged in fast processing and evaluating of the information presented, and subsequently quickly switched to implementation of a choice; both of which occurred faster within the more consequential scenarios. The third experiment (Chapter IV) analysed the effect that the simultaneous presentation of both scenario context and choice alternatives had on response times. Results showed that the differences observed previously did not hold up in this design of the decision paradigm, as more information had to be processed and evaluated within a similar time-frame. Moreover, there were no differences between the scenario conditions, illustrating once again the early activation observed in Experiment 1, when incorporating neurocognitive measurements, as this version of the task did not allow for an early/prior evaluation and deliberation.

After clarifying some of the questions related to the initial findings and the overall validity of the decision paradigm, the final two experiments assessed the effect of additional information on the decision-making process. These added a dimension on which to assess variations in evaluation, deliberation and implementation of decisions, incorporating different levels of clarity and relevance of the information available during the task.

One experiment (Chapter V) was designed around established findings relating to the Reverse Stroop Effect, looking at attentional focus as a reference point during the decision-making process. The emphasis was around the effect that meaningful information along different levels of complexity had on cognitive processing, and comparing this against conditions absent of any information. Results pointed to a shift of emphasis during the decision task, as expected, where the information variations had an effect on brain activation and response times, while scenario conditions did not affect performance. Response times for congruent information were shortest, while there were no differences between the times for the decisions made based on incongruent information or where information was lacking entirely. While distinct processing stages were identified along the lines of the basic decision-making model, no clear differentiation was possible between the information conditions in terms of activated brain regions and distinct neurocognitive processes.

The last experiment (Chapter VI) focused on more complex variations in processing by analysing differences in the clarity of task-relevant information, as well as the need to identify superfluous information. Results were in line with expectations, with a trend for response times being increasingly longer when more complex information was made available, while task-irrelevant information resulted in the longest response delay. These variations also mapped onto the basic decision-making model, identifying individual stages of neurocognitive processing and their effect on brain activation, based on individual components, and subsequent response times. Similar to the previous experiment, the scenario conditions did not have an effect on response times, once again highlighting the importance of available information, rather than the operational setting in which it is received. This was carried over in the two last experiments, even when considering conditions with no or superfluous information.

The outline of these general results provides an overview of the individual findings and their relationship within the thesis. They point towards the comparative framework on which to further expand the research into fundamental neurocognitive processes, and how these interact in similar forced-choice decision environments. Therefore, it is important to highlight how the key conceptual findings from each of the experiments contribute to the existing theoretical and applied areas of research. Finally, some additional methodological weaknesses of the current studies and improvement for future work will be discussed.

2.1 Emotion

In the first instance, emotional affect, as influenced by the varying levels of consequential conditions in the operational settings, had an effect on decision-making when no other information was available on which to base any evaluative judgements. This supported the Somatic Marker Hypothesis (Damasio, 1994), which states that emotional feelings are biasing factors that drive behaviour (Craig, 2008). In the present studies, more emotional scenarios led to faster decision implementation. This was in opposition to the expectations of heightened anticipated regret leading to decision delay (Zeelenberg, van Dijk, Manstead, & van der Pligt, 2000; Anderson, 2003; Lipshitz, 2005). However, when additional information was presented, emotional affect did not play a role in the decision process, as cognitive demands produced the observed variations in decision delay.

These findings further contribute to studies highlighting the complex role that emotions play in decision making (Pfister & Böhm, 2008) by identifying whether emotions are simply an aid to cognition, by helping individuals to weigh decisions correctly, or whether the role they play is more fundamental to the decision process. To reiterate, results from the initial experiment reported within this thesis pointed to a deeper implication of emotions in line with the primacy of affect (Zajonc, 1980; Kinsbourne, 1988). However, latter results reported in Chapter V and VI (Experiments 4 & 5) indicated that the premise that emotions and regulatory feelings have stronger effects on cognitions than vice versa (Panksepp, 1998) did not hold true in this particular decision paradigm.

These findings do not question established ideas about the effect emotion has on decision making and their overall role within cognitive processing. On the contrary, they are in line with current ideas around their complex influence in problem-solving (Naqvi, Shiv, & Bechara, 2006) and their effect on neurocognitive processes (Davidson & Irwin, 1999; Davidson, 2003). Despite this, it was not the goal of this thesis to explore and identify the complexities of how emotion influences decision making in forced choice environments. These were included in the current studies due to a recognition of the need to incorporate considerations about affect within decision making (Loewenstein & Lerner, 2003; Mosier & Fisher, 2009); and served to create a reference point and as a method through which to induce increasingly complex cognitive demands.

2.2 Information

The decision-paradigm designed in the current thesis focused on heightening performance pressure, where deciding "well" meant deciding *expeditiously*. Time was therefore of the essence, and the design required individuals to decide within a time frame, based on Johnson-Laird and Shafir's basic interaction model (Johnson-

Laird & Shafir, 1993), deemed appropriate for the problem at hand. Within these conditions, the predominant focus assessed the role information plays in decision-making in a forced-choice environment, through an assessment of reasoning and its influence on task performance at a neurocognitive level.

In line with expectations about information processing, results from this framework confirmed the different effects observed when clear or complex information is presented to individuals. Furthermore, different behavioural responses were observed when individuals were processing either task-relevant or superfluous information. These results provide a confident reference point on which to frame proposals around the identification of unique decision-making stages (Gollwitzer, et al., 1990) and how these were affected by information. Ultimately, these references provided an additional level of explanation for the differences in behavioural measures, reflected in the response times for each task condition, based on the variations in consequential affect and information availability.

On a neurological level, as set out by contributions within the area of decision neuroscience (Fellows, 2004; Gold & Shadlen, 2007), the goal was to advance our understanding of the validity of mapping these unique processes within regions of the brain. Based on the particular decision paradigm, distinct processes included those observed for:

1) simple information, directly identifying the value of the input;
2) more complex information, requiring more cognitive effort to identify the validity of the input;
3) the absence of any information, which led to the activation of an individual problem-solving strategy; and,
4) superfluous information, which required the recognition of this input as task-irrelevant, and the subsequent shift to an individual problem-solving strategy.

Each of these resulted in differences in terms of brain activation and response times, in line with expectations. Additionally, one might have expected to find differences in source localisation, considering that the more complex types of information lead to different cognitive processes. On the one hand, one required making sense of the information at hand, while the other two required individuals to move past the absent or superfluous information, onto deliberation under uncertain conditions. This particular decision paradigm did not point to differences in localisation, based on the available recordings of brain activation.

While questions about the attentional differences in each condition have been addressed in previous studies (Posner & Petersen, 1990; Rugg, 1995; Ward, 1999; Luck, Woodman, & Vogel, 2000), and results from this thesis were in line with those findings, it was difficult to draw concrete conclusions about the similarities observed in the localised activation results. These findings may point to the fact that despite the differences found, all three types of information still resulted in similar activation. However, as mentioned previously, the data did not make it possible to draw any clear conclusion. Furthermore, there were some overall methodological issues that needed to be highlighted, to better understand the limitations within these findings and to provide a realistic scope provided by this framework.

3. Methodology

The inclusion of neurological measures to the study of decision making was aimed at identifying the fundamental and basic processes at play within a meaningful framework, building on their ability to identify influential factors. In this particular paradigm, the goal was to contribute knowledge beyond the area of traditional decision-making, incorporating cognitive processes usually observed within the naturalistic decision-making perspective, and induced by the unique environmental characteristics.

Keeping in mind the complex and time-compressed nature of these environments, the focus was on drawing insight into these processes using electro-encephalographic (EEG) data. With the advantage of having a high temporal resolution, EEG techniques provide a more detailed picture of the decision-making process as a whole, by combining measurements of reaction time and identification of event-related potential (ERP) components. These provide a time-locked reference point from which to assess the effect of the particular advice or scenario stimuli on brain activation, and subsequent activation relating to the decision-making process. But these advantages come at the cost of diminished localisation of these sources, which confounded some of the conclusions drawn about the observed brain activity. This was particularly true of the inferences drawn with regards to which regions of the brain were activated by particular stimuli and during individual decision-making stages when information was available processed.

The brain is a single, integrated, and highly dynamic system. Thus, especially when dealing with complex cognitive and emotional events, all references to localisation need to be understood in that context. While this thesis combined EEG, behavioural and qualitative measures, it did not include any details around functional magnetic resonance imaging (fMRI), subjects with brain lesions, or experiments incorporating transcranial magnetic stimulation (TMS). These techniques have been included in other studies when drawing conclusions about localised activity, as they have a much greater spatial resolution than EEGs. While remaining conscious of the limited correlational evidence in terms of source localisation and specific differences for the observed activation, and in particular when trying to differentiate between variations around complex information processing, the current results nevertheless provided sufficient evidence to illustrate the validity of applying this approach to an analysis of basic decision-making processes.

3.1 Visual Processing

One weakness highlighted within the individual experiments pointed to the vision-related activation described for each particular stimulus. The design, focused on setting operational context using different images to represent a unique scenario, did not allow meaningful conclusions to be drawn from the recordings relating to the presentation of the stimuli. Differences were observed between the individual consequence conditions, but it was not clear whether these related to the stimuli used or the context they represented. More meaningful conclusions could have been drawn if simple text was used to represent the context, avoiding any differences relating to the visual complexity of the stimuli. Additionally, this might have heightened participants' immersion in the contextual settings, drawing from their own imagination to place themselves in the particular operational scenarios. This would also lower the activation observed in the visual-processing regions, potentially raising activation in other areas relating to the emotional differences induced by the task. While visual processing was not a priority within this decision paradigm, this issue served as a reminder about the difficulty of confidently drawing correlational conclusions from neurological measures and related cognitive processes.

3.2 Decision-making Stages

Similarly, other shortcomings related to the limited insight gained into more specific processes identified during individual decision-making stages. Additional studies which focus on those unique processes should be developed, in order to further identify neurocognitive activation and isolate those regions. Building on the framework presented in this research, a number of processes were observed, and more specific experiments would further advance any potential insight.

One possible experiment would look more closely into details around frame-shifting activity (Monsell, 2003), in conditions were individuals had to apply their own decision strategy. This would be based on a version where the order of the decisions and how often positive feedback followed negative feedback (and vice-versa) are pre-set. This would allow focusing on the effect the need to reconsider ones choices would have on cognitive processing. Significant differences between those responses following correct vs. incorrect feedback would point to individuals' active re-assessment (i.e. frame-shifting) of their strategy. Each task would require its own configuration (or schema) in order to reach a specific goal, where the shift would involve discarding a previous schema and establishing a new one; this difference in response time between switch and non-switch trials is known as switch cost (Rogers & Monsell, 1995).

Activation in the prefrontal lobe in some of the experiments hinted to this process, in line with previous findings around frame-shifting (Coulson, 2001; Nagahama, et al. 2001; Rubia, Smith, Brammer, & Taylor, 2003), reflected in the ability to respond flexibly to the changing demands (Ruff, Allen, Farrow, Niemann,

& Wylie, 1994; Heilman, 2005; Picton, Stuss, Alexander, Shallice, Binns, & Gillinghman, 2007). Previous research has also pointed to this switch cost within the Stroop Test, changing from easy to hard and back (Allport, Styles, & Hsieh, 1994), where the cost relates more to the suppression of the old task, rather than the setting up of the new one. A re-design of the decision paradigm would make it possible to compare these conditions, isolating the evaluation and implementation stages, in order to look at unique differences. Additionally, this design would also allow for the identification of processing immediately following feedback. Expectations here would focus on executive functions in sources located in the anterior cingulate and its role in error detection (Carter, Braver, Brach, Botvinick, Noll, & Cohen, 1998), and look at activity relating to behavioural adjustment (following incorrect choices), resulting in greater activity for negative feedback in the prefrontal cortex (Kerns, Cohen, MacDonald, Cho, Stenger, & Carter, 2004).

Similarly, considering the possibilities of developing further research into the particular decision-making stages, one expansion would see the focus on learning within a task. Creating a solvable version of the decision paradigm, where individuals can move from a level of novices to experts, through the training of solution patterns. This would allow looking into fundamental aspects of the development of expertise within a task, in particular when focusing on the recognition-primed decision model (Klein, 1993; Ericsson, Charness, Feltovich, & Hoffman, 2006). Such design would map onto the basic decision-making model, looking at activity during the learning phase, moving onto the recognition and targeting of the solution pattern, and finally the implementation of decisions. This would advance the current framework one step further, not only identifying the 3-stage decision-making model, but also incorporating the active targeting of attention and cognitive processing to a solvable task.

Beyond these concrete examples, the findings within this thesis demonstrate the potential of applying this methodological approach to the focused research around decision-making. While some weaknesses remain, in terms of the reliable drawing of conclusions about more complex processes as well as the ability to isolate unique processes within particular task conditions, the findings overwhelmingly point to the potential of adding neurological measurements. As highlighted above, it is important to recognise from the beginning the limitations, and design clear and simple experiments, focused on basic factors, in order to slowly build a more complete picture of interrelated brain activity and a continuous narrative of the cognitive decision-making process.

4. Conclusion

The key findings from this thesis reflect its contribution as a framework piece, bringing together a number of research areas, in order to provide an additional comparative level of research. Addressing some fundamental aspects of decision-making, identifying factors characteristic to forced-choice environments in situations of high-risk and uncertainty, the thesis combines different measurements to present a richer narrative about the cognitive processes and how they are affected. Recognising that the prime challenge in these environments lies in the need to choose between two equally (un)attractive options, under conditions of high time pressure and significant risk, results here contribute to the fundamental understanding of the interplay between performance pressures and information, and how these affect individuals' response.

As observed in the basic decision paradigm, when individuals had information available to make a choice, then emotion did not influence their response. This was also valid with superfluous information, where the deliberation about the decision still had no meaningful point of reference. More effortful information resulted in similar activation, even when one piece of information was meaningful to the solution of the task and the other one was not. The EEG measurements provided a good temporal resolution, at the expense of some spatial accuracy, focusing on the narrow time window and the particular experimental design around the key decision-making stages. This demonstrated that further contributions could be made towards basic decision-making, using this as an additional measure of insight. Some questions do remain about the methodological confidence, but results point to some clear differences in terms of information processing and neurocognitive descriptions to behavioural measures. The key challenge here remains, as with all approaches aimed at advancing more in-depth insights, to confidently unfold the individual processes, before putting them back together within the dynamic and complex framework they were taken from.

References

REFERENCES

Allison, T., Woods, C. C., & McCarthy, G. M. (1986). The central nervous system. In M. G. H. Coles, E. Donchin, & S. W. Porges (Eds.), *Psychophysiology: Systems, processes and applications* (pp. 54–68). New York, NY: Guilford Press.

Anderson, C. J. (2003). The psychology of doing nothing: Forms of decision avoidance result from reason and emotion. *Psychological Bulletin, Vol. 129, No. 1*, pp. 139–167.

Asaad, W. F., Rainer, G., & Miller, E. K. (1998). Neural activity in the primate prefrontal cortex during associative learning. *Neuron, Vol. 21, Issue 6*, pp. 1399-1407.

Asaad, W. F., Rainer, G., & Miller, E. K. (2000). Task-specific neural activity in the primate prefrontal cortex. *Journal of Neurophysiology, Vol. 84, No. 1*, pp. 451-459.

Aschenbrenner, K. M., Böckenholt, U., Albert, D., & Schmalhofer, F. (1986). The effects of attractiveness, dominance, and attribute differences on information acquisition in multiattribute binary choice. *Organizational Behavior & Human Decision Processes, Vol. 49, Issue 2*, pp. 258-281.

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology, Vol. 49A, No. 1*, pp. 5-28.

Badzakova-Trajkov, G., Barnett, K. J., Waldie, K. E., & Kirk, I. A. (2009). An ERP investigation of the Stroop task: The role of the cingulate in attentional allocation and conflict resolution. *Brain Research, Vol. 1253*, pp. 139-148.

Bagozzi, R. P. Dholakia, U. M. & Basuroy, S. (2003). How effortful decisions get enacted: The motivating role of decision processes, desires, and anticipated emotions. *Journal of Behavioral Decision Making, Vol. 16, Issue 4*, pp. 273-295.

Baird, A. A., & Fugelsang, J. A. (2004). The emergence of consequential thought: Evidence from neuroscience. *Philosophical Transactions of the Royal Society B: Biological Sciences, Vol. 359, No. 1451*, pp. 1797-1804.

Ball, T., Schreiber, A., Feige, B., Wagner, M., Lücking, C. H., & Kristeva-Feige, R. (1999). The role of higher-order motor areas in voluntary movement as revealed by high-resolution EEG and fMRI. *Neuroimage, Vol. 10, Issue 6*, pp. 682-694

Barlas, S. (2003). When choices give in to temptations: Explaining the disagreement among importance measures. *Organizational Behavior and Human Decision Processes, Vol. 91, No. 2*, pp. 310-321.

Baron, J. (1994). *Thinking and deciding (2nd Edition)*. Cambridge, UK: Cambridge University Press.

Bartholow, B. D., & Amodio, D. M. (2009) Using event-related brain potentials in social psychological research: A brief review and tutorial. In E. Harmon-Jones & J. S. Beer (Eds.), Methods in Social Neuroscience (pp. 198-232). New York: Guilford Press.

Baxter, M. G. & Murray, E. A. (2002). The amygdala and reward. *Nature Reviews Neuroscience, Vol. 3*, pp. 563-573.

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition, Vol. 50, Issues 1-3*, pp. 7-15.

Bench, C. J., Frith, C. D., Grasby, P. M., Friston, K. J., Paulesu, E., & Frackowiak, R. S. J. (1993). Investigations of the functional anatomy of attention using the Stroop test. *Neuropsychologia, Vol. 31, Issue 9*, pp. 907-922.

Blais, C., & Besner, D. (2007). A reverse Stroop effect without translation or reading difficulty. *Psychonomic Bulletin & Review, Vol. 14, No. 3*, pp. 466-469.

Boschert, J., Hink, R. F., & Deecke, L. (1983). Finger movement versus toe movement-related potentials: Further evidence for supplementary motor area (SMA) participation prior to voluntary action. *Experimental Brain Research, Vol. 52, No. 1*, pp. 73-80.

Böckenholt, U., Albert, D., Aschenbrenner, K. M., & Schmalhofer, F. (1991). The effects of attractiveness, dominance, and attribute differences on information acquisition in multiattribute binary choice. *Organizational Behavior & Human Decision Processes, Vol. 49, Issue 2*, pp. 258-281.

Bötzel, K., Plendl, H., Paulus, W., & Scherg, M. (1993). Bereitschaftspotential: Is there a contribution of the supplementary motor area? *Electroencephalography and Clinical Neurophysiology, Vol. 89, Issue 3*, pp. 187-196.

Bradley, M. M., Sabatinelli, D., Lang, P. J., Fitzsimmons, J. R., King, W., & Desai, P. (2003). Activation of the visual cortex in motivated attention. *Behavioral Neuroscience, Vol. 117, Issue 2*, pp. 369-380.

Brass, M., & Haggard, P. (2007). To do or not to do: The neural signature of self-control. *Journal of Neuroscience, Vol. 27, Issue 34*, pp. 9141-9145.

Breiter, H. C. & Rosen, B. R. (1999). Functional magnetic resonance imaging of brain reward circuitry in the human. *Annals of the New York Academy of Sciences, Vol. 877*, pp. 523-547.

Breiter, H. C., Aharon, I., Kahneman, D., Dale, A. & Shizgal, P. (2001). Functional imaging of neural responses to expectancy and experience ofmonetary gains and losses. *Neuron, Vol. 30, Issue 2*, pp. 619-639.

Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences, Vol. 4, No. 6*, pp. 215-222.

Bush, G., Vogt, B. A., Holmes, J., Dale, A. M., Greve, D., Jenike, M. A. & Rosen, B. R. (2002). Dorsal anterior cingulate cortex: A role in reward-based decision making. *Proceedings of the National Academy of Sciences of the United States of America, Vol. 99, No.1*, pp. 523-528.

Cabeza, R., Dolcos, F., Prince, S. E., Rice, H. J., Weissman, D. H., & Nyberg, L. (2003). Attention-related activity during episodic memory retrieval: A cross-function fMRI study. *Neuropsychologie, Vol. 41, Issue 3*, pp. 390-399.

Cacioppo, J. T., & Berntson, G. G. (1992). Social psychological contributions to the decade of the brain: Doctrine of multilevel analysis. *American Psychologist, Vol. 47, No. 8*, pp. 1019-1028.

Cacioppo, J. T., Gardner, W. L., & Bernston, G. G. (1999). The affect system has parallel and integrative processing components: Form follows function. *Journal of Personality and Social Psychology, Vol. 76, Issue 5*, pp. 839-855.

Cacioppo, J. T., Visser, P. S., & Pickett, C. L. (2005). *Social neuroscience: People thinking about thinking people*. Cambridge, MA: MIT Press.

Cacioppo, J. T., Bernston, G. G., & Decety, J. (2010). Social neuroscience and its relationship to social psychology. *Social Cognition, Vol. 28, No. 6*, pp. 675-685.

Cannon-Bowers, J. A., & Salas, E. (1998). Individual and team decision making under stress: Theoretical underpinnings. In J. A. Cannon-Bowers & E. Salas (Eds.), *Making decisions under stress* (pp. 17-38). Washington, DC: APA.

Carter, C. S., & van Veen, V. (2007). Anterior cingulate cortex and conflict detection: An update of theory and data. *Cognitve Affective and Behavioral Neuroscience, Vol. 7, No. 4,* pp. 367-379.

Carter, C. S., Braver, T. S., Brach, D. M., Botvinick, M. M., Noll, D., & Cohen, J. D. (1998). Anterior cingulate cortex, error detection, and the online monitoring of performance. *Science, Vol. 280, No. 5364*, pp. 747-749.

Carter, C. S., MacDonald, A. M., Botvinick, M., Ross, L. L., Stenger, V. A., Noll, D., & Cohen, J. D. (2000). Parsing executive processes: Strategic vs. evaluative functions of the anterior cingulate cortex. *Proceedings of the National Academy of Science, USA, Vol. 97, No. 4*, pp. 1944-1948.

Clore, G. L. (1992). Cognitive phenomenology: Feelings and the construction of judgments. In L. L. Martin & A. Tesser (Eds.), *The construction of social judgments* (pp. 133–163). Hillsdale, NJ: Lawrence Erlbaum Associates.

Clore, G. L., Schwarz, N. & Conway, M. (1994). Affective causes and consequences of social information processing. In R. S. Wyer & T. K. Srull (Eds.), *Handbook of social cognition* (pp. 323-369). Hillsdale, NJ: Lawrence Erlbaum Associates.

Coles, M. G. H. (1989). Modern mind-brain reading: Psychophysiology, physiology, and cognition. *Psychophysiology, Vol. 26, Issue 3*, pp. 251-269.

Coles, M. G. H., & Rugg, M. D. (1995). Event-related potentials: An introduction. In M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of Mind* (pp. 1-26). Oxford: University Press.

Coles, M. G. H., Gratton, G., & Donchin, E. (1988). Detecting early communication: Using measures of movement-related potentials to illuminate human information processing. *Biological Psychology, Vol. 26, Issues 1-3*, pp. 69-89.

Coles, M. G. H., Gratton, G., Bashore, T. R., Eriksen, C. W., & Donchin, E. (1985). A psychophysiological investigation of the continuous flow model of human information processing. *Journal of Experimental Psychology: Human Perception and Performance, Vol. 11, No. 5*, pp. 529-553.

Collyer, S. C., & Malecki, G. S. (1998). Tactical decision making under stress: History and overview. In J. A. Cannon-Bowers & E. Salas (Eds.), *Making decisions under stress* (pp. 3-16). Washington, DC: APA.

Conklin, J. (2005). *Dialogue mapping: Building shared understanding of wicked problems*. New York, NY: Wiley & Sons.

Cooper, R., & Shallice, T. (2000). Contention scheduling and the control of routine activities. *Cognitive Neuropsychology, Vol. 17, Issue 4*, pp. 297-338.

Coulson, S. (2001). *Semantic leaps: frame-shifting and conceptual blending in meaning construction*. Cambridge: University Press.

Craig, B. (2008). Interoception and emotion: A neuroanatomical perspective. In M. Lewis, J. M. Haviland-Jones & L. F. Barrett (Eds), *Handbook of Emotion (3rd Edition)* (pp. 272–290). London: Guildford Press.

Damasio, A. R. (1994). *Descartes' error: Emotion, reason and the human brain*. New York: Putnam & Sons.

Davidson, R. J. (2003). Affective neuroscience and psychophysiology: Toward a synthesis. *Psychophisiology, Vol. 40*, pp. 655-665.

Davidson, R. J., & Sutton, S. K. (1995). Affective neuroscience: The emergence of a discipline. *Current Opinion in Neurobiology, Vol. 5, Issue 2*, pp. 217-224.

Davidson, R. J, & Irwin, W. (1999). The functional neuroanatomy of emotion and affective style. *Trends in Cognitive Sciences, Vol. 3, No. 1*, pp. 11-21.

Davidson, R. J., Ekman, P., Saron, C. D., Senulis, J. A., & Friesen, W. V. (1990). Approach-withdrawal and cerebral asymmetry: Emotional expression and brain physiology. *Journal of Personality and Social Psychology, Vol. 58, Issue 2*, pp. 330-341.

Deecke, L., Scheid, P., & Kornhuber, H. H. (1969). Distribution of readiness potential, pre-motion positivity, and motor potential of the human cerebral cortex preceding voluntary finger movements. *Experimental Brain Research, Vol. 7, No. 2*, pp. 158-168.

De Jong, R., Wierda, M., Mulder, G., & Mulder, L. J. M. (1988). Use of partial stimulus information in response processing. *Journal of Experimental Psychology: Human Perception and Performance, Vol. 14, No. 4*, pp. 682-692.

Devinski, O., Morrell, M. J., & Vogt, B. A. (1995). Contributions of anterior cingulate cortex to behaviour. *Brain, Vol. 118, Issue 1*, pp. 279-306.

Duncan, J., & Owen, A. M. (2000). Common regions of the human frontal lobe recruited by diverse cognitive demands. *Trends in Neuroscience, Vol. 23, Issue 10*, pp. 475-483.

Durgin, F. H. (2000). The reverse Stroop effect. *Psychonomic Bulletin & Review, Vol. 7, No. 1*, pp. 121-125.

Elliot, R., Dolan, R. J., & Frith, C. D. (2000). Dissociable functions in the medial and lateral orbitofrontal cortex: Evidence from human neuromaging studies. *Cerebral Cortex, Vol. 10, Issue 3*, pp. 308-317.

Ericsson, K. A., Charness, N., Feltovich, P. J., & Hoffman, R. R. (2006). *The Cambridge handbook of expertise and expert performance: Its development, organization, and content*. Cambridge: University Press.

Fabiani, M., Gratton, G., & Coles, M. G. H. (2000). Event-related brain potentials. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (2nd Edition) (pp. 53-84). Cambridge: Cambridge University Press.

Fecteau, S. Knoch, D. Fregni, F. Sultani, N. Boggio, P., & Pascual-Leone, A. (2007). Diminishing risk-taking behavior by modulating activity in the prefrontal cortex: A direct current stimulation study. *Journal of Neuroscience, Vol. 27, No. 46*, pp. 12500-12505.

Fellows, L. K. (2004). The cognitive neuroscience of human decision making: A review and conceptual framework. *Behavioral and Cognitive Neuroscience Reviews, Vol. 3, No. 3*, pp. 159-172.

Fiore, S. M., Rosen, M. A., & Salas, E. (2011). Uncertainty management and macrocognition in teams. In K. L. Mosier & U. M. Fischer (Eds.), *Informed by knowledge: Expert performance in complex situations* (pp. 247-260). London: Psychology Press.

Flowers, J. H. (1975). "Sensory" interference in a word-color matching task. *Attention, Perception & Psychophysics, Vol. 18, No. 1*, 37-43.

Frith, C. D., Kriston, K., Liddle, P. F., & Frackowiak, R. S. J. (1991). Willed action and the prefrontal cortex in a man: A study with PET. *Proceedings of the Royal Society of London, Vol. 244, No. 1311*, pp. 241-246.

Fuster, J. M. (2001). The prefrontal cortex – an update: Time is of the essence. *Neuron, Vol. 30, No. 2*, pp. 319-333.

Gehring, W. J., Gratton, G., Coles, M. G. H., & Donchin, E. (1992). Probability effects on stimulus evaluation and response processes. *Journal of Experimental Psychology: Human Perception and Performance, Vol. 18, Issue 1*, pp. 198-216.

Gehring, W. J., & Willoughby, A. R. (2002). The medial frontal cortex and the rapid processing of monetary gains and losses. *Science, Vol. 295, No. 5563*, pp. 2279-2282.

Gigerenzer, G. & Todd, P. M. (1999). *Simple heuristics that make us smart*. Oxford: University Press.

Glimcher, P. W., & Rustichini, A. (2004). Neuroeconomics: The consilience of brain and decision. *Science, Vol. 306, No. 5695*, pp. 447-452.

Gilbert, S. J., Spengler, S., Simons, J. S., Steele, J. D., Lawrie, S. M., Frith, C. D., & Burgess, P. W. (2006). Functional specialization within rostral prefrontal cortex (area 10): A meta-analysis. *Journal of Cognitive Neuroscience, Vol. 18, No. 6*, pp. 932-948.

Gilbert, S. J., Zamenopoulos, T., Alexiou, K., & Johnson, J. H. (2010). Involvement of right dorsolateral prefrontal cortex in ill-structured design cognition: An fMRI study. *Brain Research, Vol. 1312*, pp. 79-88.

Glimcher, P. W., & Rustichini, A. (2004). Neuroeconomics: The consilience of brain and decision. *Science, Vol. 306, No. 5695*, pp. 447-452.

Glimcher, P. W., Camerer, C. F., Fehr, E., & Poldrack, R. A. (2008). *Neuroeconomics: Decision making and the brain*. London: Academic Press.

Gold, J. I., & Shadlen, M. N. (2007). The neural basis of decision making. *Annual Review of Neuroscience, Vol. 30*, pp. 535-574.

Goldberg, E. (2001). *The executive brain: Frontal lobes and the civilized mind*. Oxford: University Press.

Gollwitzer, P.M., Heckhausen, H., & Steller, B. (1990). Deliberative and implemental mind-sets: Cognitive tuning toward congruous thoughts and information. *Journal of Personality and Social Psychology, Vol. 59, No. 6*, pp. 1119-1127.

Greenwald, A. G., & Banaji, M. R. (1995). Implicit social cognition: Attitudes, self-esteem, and stereotypes. *Psychological Review, Vol. 102, Issue 1*, pp. 4-27.

Habib, R., Nyberg, L., & Tulving, E. (2003). Hemispheric asymmetries of memory: The HERA model revisited. *Trends in Cognitive Sciences, Vol.7, Issue 6*, pp. 241.245.

Haggard, P., & Eimer, M. (1999). On the relation between brain potentials and the awareness of voluntary movements. *Experimental Brain Research, Vol. 126, No. 1*, pp. 128-133.

Hamm, A. O., Schupp, H. T., & Weike, A. I. (2003). Motivational organization of emotions: Autonomic changes, cortical responses, and reflex modulation. In R. Davidson, K. Scherer & H. Goldsmith (Eds.), *Handbook of affective sciences* (pp. 187-211). Oxford: University Press.

Handy, T. C. (2005). *Event-related potentials: A method handbook.* Cambridge, MA: MIT Press.

Harmon-Jones, E. (2003). Clarifying the emotive functions of asymmetrical frontal cortical activity. *Psychophysiology, Vol. 40, Issue 6*, pp. 838-848.

Harmon-Jones, E., & Devine, P. G. (2003). Introduction to the special section on social neuroscience: Promise and caveats. *Attitudes and Social Cognition, Vol. 85, No. 4*, pp. 589-593.

Harmon-Jones, E., & Winkielman, P. (2007). *Social neuroscience: Integrating biological and psychological explanations of social behavior*. New York, NY: Guilford Press.

Harmon-Jones, E., & Beer, J. S. (2009). *Methods in social neuroscience*. New York, NY: Guilford Press.

Heilman, K. M. (2005). *Creativity and the brain*. Hove: Psychology Press.

Heinze, H. J., Mangun, G. R., Burchert, W., Hinrichs, H., Scholz, M., Münte, T. F., et al. (1994). Combined spatial and temporal imaging of brain activity during visual selective attention in humans. *Nature, Vol. 372*, pp. 543-546.

Henson, R. N. A., Rugg, M. D., Shallice, T., & Dolan, R. J., (2000). Confidence in recognition memory for words: Dissociating right prefrontal roles in episodic retrieval. *Journal of Cognitive Neuroscience, vol. 12, No. 6*, pp. 913-923.

Herrnstein, R. J., & Prelec, D. (1991). Melioration: A theory of distributed choice. *Journal of Economic Perspectives, Vol. 5, No. 3*, pp. 137-156.

Higgins, E. T., Kruglanski, A. W., & Pierro, A. (2003). Regulatory Mode: Locomotion and Assessment as Distinct Orientations. *Advances in Experimental Social Psychology, Vol. 35*, pp. 293-344.

Hillyard, S. A., & Picton, T. W. (1987). Electrophysiology of cognition. In F. Plum (Ed.), *Handbook of Physiology: Section 1. The Nervous System: Volume V. Higher Functions of the Brain, Part 2* (pp. 519-584). Bethesda: Waverly Press.

Hogan, R., & Hogan, J. C. (1982). Subjective correlates of stress and human performance. In E. A. Alluisi & E. A. Fleishman (Eds.), *Human performance and productivity: Stress and performance effectiveness* (pp. 141-163). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hogarth, R. M. (2001). *Educating intuition*. Chicago, IL: University Press.

Huber, G. P., & McDaniel, R. R. (1986). The decision-making paradigm of organizational design. *Management Science, Vol. 32, No. 5*, pp. 572-589.

Hutchins, E. (1995). *Cognition in the wild*. London: MIT Press.

Ito, T. A., Willadsen-Jensen, E., & Correll, J. (2007). Social neuroscience and social perception: New perspectives on categorization, prejudice and stereotyping. In E. Harmon-Jones & P. Winkielman (2007). *Social neuroscience: Integrating biological and psychological explanations of social behaviour* (pp. 401-424). New York, NY: Guilford Press.

Ivancevich, J. M., & Matteson, M. T. (1980). Stress and work: A managerial perspective. Glenview, IL: Scott, Foresman.

Jahanshahi, M., & Frith, C. D. (1998). Willed action and its impairments. *Cognitive Neuropsychology, Vol. 15, Issue 6 & 8*, pp. 483-533.

Janis, I., & Mann, L. (1977). *Decision making: A psychological analysis of conflict, choice, and commitment*. New York: The Free Press.

Johannes, S., Münte, T. F., Heinze, H. J., & Mangun, G. R. (1995). Luminance and spatial attention effects on early visual processing. *Cognitive Brain Research, Vol. 2*, pp. 189-205.

Johnson-Laird, P. N., & Shafir, E. (1993). The interaction between reasoning and decision-making: An introduction. *Cognition, Vol. 49*, pp. 1-9.

Jones, C. R. G, Rosenkranz, K., Rothwell, J. C., & Jahanshahi, M. (2004). The right dorsolateral prefrontal cortex is essential in time reproduction: an investigation with repetitive transcranial magnetic stimulation. *Experimental Brain Research, Vol. 158, No. 3*, pp. 366-372.

Kahneman, D., & Klein, G. (2009). Conditions for intuitive expertise: A failure to disagree. *American Psychologist, Vol. 64, Issue 6*, pp. 515-526.

Kanwisher, N., & Wojciulik, E. (2000). Visual attention: insights from brain imaging. *Nature Reviews Neuroscience, Vol. 1, Issue 2*, pp. 91-100.

Kawashima, R., Itoh, H., Ono, S., Satoh, K., Furumoto, S., Koyama, M., Yoshioka, S., Takahashi, T., Yanagisawa, T., & Fukuda, H. (1995). Activity in the human primary cortex related to arm and finger movements. *Neuroreport, Vol. 6, Issue 2*, pp. 238-240.

Keeney, R. L., & Raiffa, H. (1976). *Decisions with multiple objectives: Preferences and value tradeoffs*. New York, NY: Wiley & Sons.

Kerns, J. G., Cohen, J. D., MacDonald, A. W., Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science, Vol. 303, No. 5660*, pp. 1023-1026.

Kinsbourne, M. (1988). Integrated field theory of consciousness. In A.J. Marcel & E. Bisiach (Eds.), *Concept of consciousness in contemporary science* (pp. 239-256). Oxford: Oxford University Press.

Klein, G. A. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. A.Klein, J.Orasanu, R.Calderwood, & C.Zsambok (Eds.), *Decision making in action: Models and methods* (pp. 138-147). Norwoord: Ablex.

Klein, G., Orasanu, J., Calderwood, R., & Zsambok, C. E. (1993). *Decision making in action: Models and methods*. Norwood, NJ: Ablex.

Knutson, B., Adams, C.M., Fong, G.W., & Hommer, D. (2001). Anticipation of increasing monetary reward selectively recruits nucleus accumbens. *Journal of Neuroscience, Vol. 21, No. 16*, pp. 1-6.

Knutson, B., Fong, G.W., Bennett, S.M., Adams, C.M., & Hommer, D. (2003). A region of mesial prefrontal cortex tracks monetarily rewarding outcomes: Characterization with rapid event-related fMRI. *Neuroimage, Vol. 18, Issue 2*, pp. 263-272.

Knutson, B., & Peterson, R. (2005). Neurally constructing expected utility. *Games and Economic Behavior, Vol. 52, Issue 2*, pp. 305-315.

Konoroski, J. (1967). *Integrative activity of the brain: An interdisciplinary approach*. Chicago: University Press.

Kornhuber, H. H., & Deecke, L. (1965). Hirnpotentialänderungen bei Wilkürbewegungen und passiven Bewegungen des Menschen:

Bereitschaftspotential und reafferenten Potentiale. *Pflügers Archiv - European Journal of Physiology, 284, No. 1*, pp. 1-17.

Kringelbach, M. L. (2005). The orbitofrontal cortex: Linking reward to hedonic experience. *Nature Reviews Neuroscience, Vol. 6, No. 9*, pp. 691-702.

Kristeva, R., Keller, E., Deecke, L., & Kornhuber, H. H. (1979). Cerebral potentials preceding unilateral and simultaneous bilateral finger movements. *Electroencephalography and Clinical Neurophysiology, Vol. 47, Issue 2*, pp. 229-238.

Kruglanski, A. W., & Webster, D. M. (1996). Motivated closing of the mind: "Seizing" and "freezing". *Psychological Review, Vol. 103, No. 2*, pp. 263-283.

Kuo, W.-J., Sjöström, T., Chen, Y.-P., Wang, Y.-H., & Huang, C.-Y. (2009). Intuition and deliberation: Two systems for strategizing in the brain. *Science, Vol. 324, No. 5926*, pp. 519-522.

Lane R. D., Fink, G. R., Chau, P. M.-L., & Dolan, R. J. (1997). Neural activation during selective attention to subjective emotional responses. *NeuroReport, Vol. 8, Issue 18*, pp. 3969-3972.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention and the startle reflex. *Psychological Review, Vol. 97, Issue 3*, pp. 377-395.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1992). A motivational analysis of emotion: Reflex-cortex connections. *Psychological Science, Vol. 3, No.1*, pp. 44-49.

Lansbergen, M. M., van Hell, E., & Kenemans, J. L. (2007). Impulsivity and conflict in the Stroop task: An ERP study. *Journal of Psychophysiology, Vol. 21, No. 1*, pp. 33-50.

LeDoux, J. E. (1996). *The Emotional Brain*. New York: Simon & Schuster.

Lerner, J. S. & Tetlock, P. E. (1999). Accounting for the Effects of Accountability. *Psychological Bulletin, Vol. 125, No.2*, pp. 255-275.

Lipshitz, R., & Strauss, O. (1997). Coping with uncertainty: A naturalistic decision-making analysis. *Organizational Behavior and Human Decision Processes, Vol. 69, Issue 2*, pp. 149-163.

Lipshitz, R. (2005). There is more to seeing that meets the eyeball: The art and science of observation. In H. Montgomery, R. Lipshitz, & B. Brehmer (Eds.), *How professionals make decisions* (pp. 365–378). Mahwah: Lawrence Erlbaum Associates.

Lipshitz, R., Klein, G., Orasanu, J., & Salas, E. (2001). Taking stock of naturalistic decision making. *Journal of Behavioral DecisionMaking, Vol. 14, Issue 5*, pp. 331-352.

Loewenstein, G. F., & Lerner, J. (2003). The role of affect in decision making. In R. Davidson, H. Goldsmith, & K. Schere (Eds.), *The handbook of affective science* (pp. 619-642). Oxford: University Press.

Loewenstein, G. F., Weber, E. U., Hsee, C. K. & Welch, N. (2001). Risk as feelings. *Psychological Bulletin, Vo. 127, No. 2*, pp. 267-286.

Loewenstein, G. F., Rick, S., & Cohen, J. D. (2008). Neuroeconomics. *Annual Review of Psychology, Vol. 59*, pp. 647-672.

Luck, S. J. (2005). *An introduction to the event-related potential technique.* Cambridge, MA: MIT Press.

Luck, S. J., & Hillyard, S. A. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiology, Vol. 31, Issue 3*, pp. 291-308.

Luck, S. J., Woodman, G. F., & Vogel, E. K. (2000). Event-related potential studies of attention. *Trends in Cognitive Sciences, Vol. 4, Issue 11*, pp. 432-440.

MacDonald, A. W, Cohen, J. D., Stenger, V. A., & Carter, C. S. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science, Vol. 288, No. 5472*, pp. 1835-1838.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, Vol. 109, Issue 2*, pp. 163-203.

MacLeod, C. M. (1992). The Stroop task: The 'gold standard' of attentional measures. *Journal of Experimental Psychology, Vo. 121, No. 1*, pp. 12-14.

Mangun, G. R. (1995). Neural mechanisms of visual selective attention. *Psychophysiology, Vol. 32*, pp. 4-18.

Martin, M. (1981). Reverse Stroop effect with concurrent tasks. *Bulletin of the Psychonomic Society, Vol. 17*, pp. 8-9.

Mayr, U., & Kleigl, R. (2000). Task-set switching and long-term memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, Vol. 26, Issue 5*, pp. 1124-1140.

McCabe, K. (2003). Neuroeconomics. In L. Nadel (Ed.), Encyclopaedia of Cognitive Science (pp. 294-298). New York: Macmillan.

McClure, S. M., Li, J., Tomlin, D., Cypert, K. S., Montague, L. M., & Montague, P. R. (2004). Neural correlates of behavioral preference for culturally familiar drinks. *Neuron, Vol. 44, Issue 2*, pp. 379-387.

McClure, S. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2004). Separate neural systems value immediate and delayed monetary rewards. *Science, Vol. 306, No. 5695*, pp. 503-507.

Mesulam, M. M. (2003). Some anatomic principles related to behavioral neurology and neuropsychology. In T. E. Feinberg & M. J. Farah (Eds.), *Behavioral neurology and neuropsychology (2^{nd} Edition)* (pp. 45-56). New York: McGraw-Hill.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, Vol. 24, Issue 1*, pp. 359-369.

Monsell, S. (2003). Task switching. *Trends in Cognitive Neuroscience, Vol. 7, Issue 3*, pp 134-140.

Montague, P. R., & Berns, G. S. (2002). Neural economics and the biological substrates of valuation. *Neuron, Vol. 36, Issue 2*, pp. 265-284.

Mosier, K. L., & Fischer, U. M. (2009). Does affect matter in naturalistic decision making? *Proceedings of 9th International Conference on Naturalistic Decision Making - London, UK*, pp. 99-104.

Nagahama, Y., Okada, T., Katsumi, Y., Hayashi, T., Yamauchi, H., Oyanagi, C., Konishi, J., Fukuyama, H., & Shibasaki, H. (2001). Dissociable mechanisms of attentional control within the human prefrontal cortex. *Cerebral Cortex, Vol. 11, Issue 1*, pp. 85-92.

Naqvi, N., Shiv, B., & Bechara, A. (2006). The role of emotion in decision making : A cognitive neuroscience perspective. *Current Directions in Psychological Science, Vol. 15, No. 5*, pp. 260-264.

Neshige R., Lüders H., & Shibasaki H. (1988). Recording of movement-related potentials from scalp and cortex in man. *Brain, Vol. 3*, pp. 719-736.

Nieuwenhuys, R., Voogd, J., & van Huijzen, C. (2008). *The human central nervous system* (4^{th} Edition). Heidelberg: Springer Verlag.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self regulation* (pp. 1-18). New York, NY: Plenum Press.

Nunez, P. L., & Srinivasan, R. (2006). *Electric fields of the brain: The neurophysics of EEG (2nd Edition).* Oxford: University Press.

Oatley, K., Keltner, D., & Jenkins, J. M. (2006). *Understanding emotions*. Oxford: Blackwell Publishing.

O'Doherty, J., Critchley, H., Deichmann, R., & Dolan, R. J. (2003). Dissociating valence of outcome from behavioral control in human orbital and ventral prefrontal cortices. *Journal of Neuroscience, Vol. 23, No. 21*, pp. 7931-7939.

den Ouden, H. E. M., Frith, U. Frith, C., & Blakemore, S.-J. (2005). Thinking about intentions. *NeuroImage, Vol. 28, Issue 4*, pp. 787-796.

Padmala, S., & Pessoa, L. (2008). Affective learning enhances visual detection and responses in primary visual cortex. *The Journal of Neuroscience, Vol. 28, No. 24*, pp. 6202-6210.

Panksepp, J. (2008). *Affective neuroscience: The foundations of human and animal emotions*. Oxford: Oxford University Press.

Pardo, J. V., Pardo, P. J., Janer, K. W., & Raichle, M. E. (1990). The anterior cingulate cortex mediates processing selection in the Stroop attentional conflict paradigm. *Proceedings of the National Academy of Science, USA, Vol. 87, No. 1*, pp. 256-259.

Passingham, R. E. (1996). Functional specialization of the supplementary motor area in monkeys and humans. *Advances in Neurology, Vol. 70*, pp. 105-116.

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the barratt impulsiveness scale. *Journal of Clinical Psychology, Vol. 51, Issue 6*, pp. 768-774.

Paus, T. (2001). Primate anterior cingulated cortex: Where motor control, drive and cognition interface. *Nature Reviews: Neuroscience, Vol. 2, Issue 6*, pp. 417-424.

Paus, T., Petrides, M., Evans, A. C., & Meyer, E. (1993). Role of the human anterior cingulate cortex in the control of oculomotor, manual, and speech responses: A positrion emission tomography study. *Journal of Neurophysiology, Vol. 70, No. 2,* pp. 453-469.

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature, Vol. 9*, pp.148-158.

Petersen, S. E., Fox, P. T., Posner, M. I., Mintum, M., & Raichle, M. E. (1989). Positron emission tomographic studies of the cortical anatomy of single-word processing. *Journal of Cognitive Neuroscience, Vol. 1, No. 2*, pp. 153-170.

Peterson, B.S., Kane, M.J., Alexander, G.M., Lacadie, C., Skudlarski, P., Leung, H.C., Mat, J., Gore, J.C. (2002). An event-related functional MRI study comparing interference effects in the Simon and Stroop tasks. *Cognitive Brain Research, Vol. 13*, pp. 427-440.

Pfister, H. R., & Böhm, G. (2008). The multiplicity of emotions: A framework of emotional functions in decision making. *Judgment and Decision Making, Vol. 3, No. 1*, pp. 5-17.

Pham, M. T. (1998). Representativeness, relevance, and the use of feelings in decision-making. *Journal of Consumer Research, Vol. 25, No. 2*, pp. 144-159.

Phelps, E. A. (2006). Emotion and cognition: Insights from studies of the human amygdala. *Annual Review of Psychology, Vol. 57*, pp. 27-53.

Picton, T. W., Stuss, D. T., Alexander, M. P., Shallice, T., Binns, M. A., & Gillingham, S. (2007). Effects of focal frontal lesions on response inhibition. *Cerebral Cortex, Vol. 17, No. 4*, pp. 826-838.

Pochon, J. B., Levy, R., Fossati, P., Lehericy, S., Poline, J. B., Pillon, B., Le Bihan, D., & Dubois, B. (2002). The neural system that bridges reward and cognition in humans: An fMRI study. *Proceedings of the National Academy of Sciences of the United States of America, Vol. 99, No. 8*, pp. 5669-5674.

Posner, M. I., & Petersen, S. E. (1990). The attentional system of the human brain. A*nnual Review of Neuroscience, Vol. 13*, pp. 25-42.

Raghunathan, R., & Pham, M. T. (1999). All negative moods are not equal: Motivational influences of anxiety and sadness on decision making. *Organizational Behavior and Human Decision Processes, Vol. 79, No. 1*, pp 56-77.

Ramachandran, V. S. & Blakeslee, S. (2005). *Phantoms in the Brain: Probing the Mysteries of the Human Mind*. New York, NY: Harper Collins.

Richardson, R. T., & DeLong, M. R. (1991). Electrophysiological studies of the functions of the nucleus basalis in primates. In T. C. Napier, P. W. Kalivas, & I. Hanin (Eds.), *The basal forebrain: Anatomy to function* (pp. 233-252). New York, NY: Plenum Press.

Rittel, H. W. J. (1988). The Reasoning of Designers. *International Congress on Planning and Design Theory – Boston*. Institut für Grundlagen der Planung – Stuttgart.

Rittel, H. W. J., & Webber, M. (1973). Dilemmas in a general theory of planning. *Policy Sciences, Vol. 4, No. 2*, pp. 155-169.

Rogers, R. D, & Monsell, S. (1995). Costs of a predictible switch between simple cognitive tasks. *Journal of Experimental Psychology, Vol. 124, No. 2*, pp. 207-231.

Rosenfeld, J. P., & Skogsberg, K. R. (2006). P300-based Stroop study with low probability and target Stroop oddballs: The evidence still favors the response selection hypothesis. *International Journal of Psychophysiology, Vol. 60, Issue 3*, pp. 240-250.

Rubia, K., Smith, A. B., Brammer, M. J., & Taylor, E. (2003). Right inferior prefrontal cortex mediates response inhibition while mesial prefrontal cortex is responsible for error detection. *NeuroImage, Vol. 20, Issue 1*, pp. 351-358.

Ruff, R. M., Allen, C. C., Farrow, C. E., Niemann, H., & Wylie, T. (1994). Figural fluency: Differential impairment in patients with left versus right frontal lobe lesions. *Archives of Clinical Neuropsychology, Vol. 9, Issue 1*, pp. 41-55.

Rugg, M. D. (1995). Memory and consciousness: A selective review of issues and data. *Neuropsychologia, Vol. 33, Issue 9*, pp. 1131-1141.

Rumeau, C., Tzourio,N., Murayama, N., Peretti-Viton, P., Levrier, O., Joliot, Mazoyer, B., & Salamon, G. (1994). Location of hand function in the sensorimotor cortex: MR and functional correlation. *American Journal of Neuroradiology, Vol. 15, Issue 3*, pp. 567-572.

Russo, J. E., & Schoemaker, P. J. H. (1990). *Decision traps: Ten barriers to brilliant decision-making and how to overcome them*. London: Simon & Shuster.

Salas, E., Driskell, J. E., & Hughes, S. (1996). Introduction: The study of stress and human performance. In J. E. Driskell & E. Salas (Eds.), *Stress and human performance* (pp. 1-45). Mahwah, NJ: Lawrence Erlbaum Associates.

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search and attention. *Psychological Review, Vol. 84, Issue 1*, pp. 1-66.

Schwarz, N., & Clore, G. (1988). How do I feel about it? Informative functions of affective states. In K. Fiedler & J. Forgas (Eds.), *Affect, cognition and social behavior* (pp. 44–62). Toronto: Hogrefe International.

Shallice, T., & Bugress, P. (1996). The domain of supervisory processes and temporal organization of behaviour. *Philosophical Transactions of the Royal Society of London B, Vol. 351, No. 1346*, pp. 1405-1412.

Shanteau, J. (1980). *The concept of weight in judgment and decision making: A review and some unifying proposals*. Report No. 228, Centre for Research on Judgment & Policy, Institute of Behavioral Science, University of Colorado, Boulder, Colorado.

Shibasaki, H., & Kato, M. (1975). Movement-associated cortical potentials with unilateral and bilateral simultaneous hand movement. *Journal of Neurology, Vol. 208, No. 3*, pp. 191-199.

Shibasaki, H., Barrett, G., Halliday, E., & Halliday, A. M. (1980) Components of the movement-related cortical potential and their scalp topography. *Electroencephalography and Clinical Neurophysiology, Vol. 49, Issue 3-4*, pp. 213-226.

Shiffrin, R. M., Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychological Review, Vol. 84, Issue 2*, pp. 127-190.

Shiv, B., Bechara, A., Levin, I., Alba, J. W., Bettman, J. R., Dube, L., Isen, A., Mellers, B., Smidts, A., Grant, S. J., & McGraw, A. P. (2005). Decision neuroscience. *Marketing Letters, Vol. 16. No.3/4*, pp. 375-386.

Sohn, M.-H., Ursu, S., Anderson, J. R., Stenger, V. A., & Carter, C. S. (2000). The role of prefrontal cortex and posterior parietal cortex in task switching. *Proceedings of the National Academy of Sciences of the USA, Vol. 97, No. 24*, pp. 13448-13453.

Sølvberg, A., & Kung, D. (1993). *Information systems engineering: An introduction*. New York: Springer-Verlag.

Stevens, R. H., Galloway, T., & Berka, C. (2007). EEG-related changes in cognitive workload, engagement and distraction as students acquire problem solving skills. *Lecture Notes in Computer Science, Vol. 4511*, pp. 197-206.

Stolterman, E. (2008). The Nature of Design Practice and Implications for Interaction Design Research. *International Journal of Design, Vol. 2, No. 1*, pp. 55-65.

Strack, F. (1992). The different routes to social judgements: Experiential versus information strategies. In L. L. Martin & A. Tesser (Eds.), *The construction of social judgements* (pp. 249-276). Hillsdale: Lawrence Erlbaum Associates.

Strauss, E., Sherman, E. M. S., & Spree, O. (2006). *A compendium of neuropsychological tests: Administration, norms, and commentary* (3rd Edition). Oxford: Oxford University Press.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, Vol. 18, Issue 6*, pp. 643-662.

Stuss, D. T., & Levine, B. (2002). Adult clinical neuropsychology: Lessons from studies of the frontal lobes. *Annual Review of Psychology, Vol. 53*, pp. 401-433.

Stuss, D. T., Floden, D., Alexander, M. P., Levine, B., & Katz, D.(2001). Stroop performance in focal lesion patients: Dissociation of processes and frontal lobe lesion location. *Neuropsychologia 39, Issue 8*, pp. 771-786.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, Vol. 12, Issue 2*, pp. 257-285.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. New York: Springer.

Taatgen, N., & Anderson, J. R. (2009). The Past, Present, and Future of Cognitive Architectures. *Topics in Cognitive Science, Vol. 2, Issue 4*, pp. 693-704.

Talairach, J., & Tournoux, P. (1988). *Co-planar stereotaxic atlas of the human brain: 3-dimensional proportional system: An approach to cerebral imaging*. New York: Thieme Medical Publishers.

Tarkka, I. M., & Hallett, M. (1990). Cortical topography of premotor and motor potentials preceding self-paced, voluntary movement of dominant and non-dominant hands. *Electroencephalography and Clinical Neurophysiology, Vol. 75, Issues 1-2*, pp. 36-43.

Tomlinson, T. D., Huber, D. E., Riethb, C. A., & Davelaarc, E. J. (2009). An interference account of cue-independent forgetting in the no-think paradigm. *Proceedings of the National Academy of Sciences, Vol. 106*, pp. 15588-15593.

Ukai, S., Shinosaki, K., Ishii, R., Ogawa, A., Mizuno-Matsumoto, Y., Inouye, T., Hirabuki, N., Yoshimine, T., Robinson, S. E., & Takeda, M. (2002). Parallel distributed processing neuroimaging in the Stroop task using spatially filtered magnetoencephalography analysis. *Neuroscience Letters, Vol. 334, Issue 1*, pp. 9-12.

Vanderhasselt, M.-A., De Raedt, R., Baeken, C., Leyman, L., & D'haenen, H. (2006). The influence of rTMS over the right dorsolateral prefrontal cortex on intentional set switching. *Experimental Brain Research, Vol. 172, No. 2*, pp. 561-565.

Vendrell, P., Junque, C., Pujol, J., Jurado, M. A.,Molet, J., & Grafman, J. (1995). The role of prefrontal regions in the Stroop task. *Neuropsychologia, Vol. 33, No. 3*, pp. 341-352.

Vogt, B. A. (2005). Pain and emotion in interactions in subregions of the cingulated gyrus. *Nature Reviews: Neuroscience, Vol. 6, Issue 7*, pp. 533-544.

Volkmann, J., Schnitzler, A., Witte, O. W., & Freund, H.-J. (1998). Handedness and asymmetry of hand representation in human motor cortex. *Journal of Neurophysiology, Vol. 79, No. 4*, pp. 2149-2154.

Volz, K. G., Rübsamen, R., & von Cramon, D. Y. (2008). Cortical regions activated by the subjective sense of perceptual coherence of environmental sounds: A proposal for a neuroscience of intuition. *Cognitive, Affective & Behavioral Neuroscience, Vol. 8, No. 3*, pp. 318-328.

de Vries, M., Holland, R. W., & Witteman, C. L. M. (2008). In the winning mood: Affect in the Iowa gambling task. *Judgment and Decision Making, Vol. 3, No. 1*, pp. 42–50.

Vuilleumier, P., & Driver, J. (2007). Modulation of visual processing by attention and emotion: windows on causal interactions between human brain regions. *Philosophical Transactions of the Royal Society B: Biological Sciences, Vol. 362, No. 1481*, pp. 837-855.

Ward, R. (1999). Interactions between perception and action systems: A model for selective action. In G. W. Humphreys, J. Duncan, & A. Treisman (Eds.), *Attention, space and action: Studies in cognitive neuroscience* (pp. 311-332). Oxford: Oxford University Press.

Ward, J. (2010). *The student's guide to cognitive neuroscience* (2nd Edition). Hove: Psychology Press.

Wylie, G., & Allport, A. (2000). Task switching and the measurement of "switch costs." *Psychological Research, Vol. 63, No. 3-4*, pp. 212-233.

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist, Vol. 35, No. 2*, pp. 151-175.

Zeelenberg, M., van Dijk, W. W., Manstead, A. S. R., & van der Pligt, J. (2000). On bad decisions and disconfirmed expectancies: The psychology of regret and disappointment. *Cognition & Emotion, Vol. 14, Issue 4*, pp. 521-541.

Appendices

Appendix A

Experiment 1 (Chapter II)

Picture Rating Task

Examples of the picture rating task participants completed at the end of the decision making task.

OR

OR

"How emotional did you perceive the scenario represented by the image to be?"

Not At All — Low — High

OR

OR

"How affected would you feel, knowing that your wrong decision allowed the device to go off in this scenario?"

Not At All — Extremely

Appendix B

Experiment 1 (Chapter II)

Attitude Scales

Impulsivity Questionnaire

Please indicate on a scale of 1 to 5 the extent to which you agree or disagree with the following statements, where 1 = strongly disagree and 5 = strongly agree.

1. I plan tasks carefully.
2. I do things without thinking.
3. I make-up my mind quickly.
4. I am happy-go-lucky.
5. I don't "pay attention".
6. I have "racing" thoughts.
7. I plan trips well ahead of time.
8. I am self controlled.
9. I concentrate easily.
10. I save regularly.
11. I "squirm" at plays or lectures.
12. I am a careful thinker.
13. I plan for job security.
14. I say things without thinking.
15. I like to think about complex problems
16. I change jobs.
17. I act "on impulse."
18. I get easily bored when solving thought problems.
19. I act on the spur of the moment.
20. I am a steady thinker.
21. I change residences.
22. I buy things on impulse.
23. I can only think about one thing at a time.
24. I change hobbies.
25. I spend or charge more than I earn.
26. I often have extraneous thoughts when thinking.
27. I am more interested in the present than the future.
28. I am restless at the theater or lectures.
29. I like puzzles.
30. I am future oriented.

Appendix B

Experiment 1 (Chapter II)

Assessment & Locomotion Questionnaire

Please indicate on a scale of 1 to 6 the extent to which you agree or disagree with the following statements, where 1 = strongly disagree and 6 = strongly agree.

Assessment

1. I never evaluate my social interactions with others after they occur.
2. I spend a great deal of time taking inventory of my positive and negative characteristics.
3. I like evaluating other people's plans.
4. I often compare myself with other people.
5. I don't spend much time thinking about ways others could improve themselves.
6. I often critique work done by myself or others.
7. I often feel that I am being evaluated by others.
8. I am a critical person.
9. I am very self-critical and self-conscious about what I am saying.
10. I often think that other people's choices and decisions are wrong.
11. I rarely analyze the conversations I have had with others after they occur.
12. When I meet a new person I usually evaluate how well he or she is doing on various dimensions (e.g., looks, achievements, social status, clothes).

Locomotion

1. I don't mind doing things even if they involve extra effort.
2. I am a "workaholic".
3. I feel excited just before I am about to reach a goal.
4. I enjoy actively doing things, more than just watching and observing.
5. I am a "doer“.
6. When I finish one project, I often wait awhile before getting started on a new one.
7. When I decide to do something, I can't wait to get started.
8. By the time I accomplish a task, I already have the next one in mind.
9. I am a "low energy" person.
10. Most of the time my thoughts are occupied with the task I wish to accomplish.
11. When I get started on something, I usually persevere until I finish it.
12. I am a "go-getter.

Appendix B

Experiment 1 (Chapter II)

Need For Closure Questionnaire

Please indicate on a scale of 1 to 5 the extent to which you agree or disagree with the following statements, where 1 = strongly disagree and 5 = strongly agree.

1. I think that having clear rules and order at work is essential for success.
2. Even after I've made up my mind about something, I am always eager to consider a different opinion.
3. I don't like situations that are uncertain.
4. I dislike questions which could be answered in many different ways.
5. I like to have friends who are unpredictable.
6. I find that a well ordered life with regular hours suits my temperament.
7. When dining out, I like to go to places where I have been before so that I know what to expect.
8. I feel uncomfortable when I don't understand the reason why an event occurred in my life.
9. I feel irritated when one person disagrees with what everyone else in a group believes.
10. I hate to change my plans at the last minute.
11. I don't like to go into a situation without knowing what I can expect from it.
12. When I go shopping, I have difficulty deciding exactly what it is that I want.
13. When faced with a problem I usually see the one best solution very quickly.
14. When I am confused about an important issue, I feel very upset.
15. I tend to put off making important decisions until the last possible moment.
16. I usually make important decisions quickly and confidently.
17. I would describe myself as indecisive.
18. I think it is fun to change my plans at the last moment.
19. I enjoy the uncertainty of going into a new situation without knowing what might happen.
20. My personal space is usually messy and disorganized.
21. In most social conflicts, I can easily see which side is right and which is wrong.
22. I tend to struggle with most decisions.
23. I believe that orderliness and organization are among the most important characteristics of a good student.
24. When considering most conflict situations, I can usually see how both sides could be right.
25. I don't like to be with people who are capable of unexpected actions.
26. I prefer to socialize with familiar friends because I know what to expect from them.
27. I think that I would learn best in a class that lacks clearly stated objectives and requirements.

28. When thinking about a problem, I consider as many different opinions on the issue as possible.
29. I like to know what people are thinking all the time.
30. I dislike it when a person's statement could mean many different things.
31. It is annoying to listen to someone who cannot seem to make up his or her mind.
32. I find that establishing a consistent routine enables me to enjoy life more.
33. I enjoy having a clear and structured mode of life.
34. I prefer interacting with people whose opinions are very different from my own.
35. I like to have a place for everything and everything in its place.
36. I feel uncomfortable when someone's meaning or intention is unclear to me.
37. When trying to solve a problem I often see so many possible options that it's confusing.
38. I always see many possible solutions to problems I face.
39. I'd rather know bad news than stay in a state of uncertainty.
40. I do not usually consult many different opinions before forming my own view.
41. I dislike unpredictable situations.
42. I dislike the routine aspects of my work (studies).

Appendix C

Experiment 2 (Chapter III) & 3 (Chapter IV)

Task Experience

1. Based on the trials you just completed, what percentage did you get correct?

0%										100%

2. During the previous trials, I was concentrating hard on solving the task.

Disagree									Agree

3. During the previous trials, I figured out what the solution was.

Disagree									Agree

4. Based on the feedback I received, I revised my strategy.

Disagree									Agree

Looking at the statements below, please indicate the extent to which they describe your experience of this set of trials.

5. I felt stressed.

Disagree									Agree

6. I felt anxious.

Disagree									Agree

7. I felt under pressure to act quickly.

Disagree									Agree

8. I felt under pressure to be accurate.

Disagree									Agree

Appendix D

Experiment 2 (Chapter III) & 3 (Chapter IV)

Post-Task Questionnaire

Participant ID : ________________________ Age: ________________________

Date: ________________________ Gender: ________________________

Please read the questions below and answer them truthfully.

1. On a scale of 1 to 10 (i.e. 1 = *not at all*, and 10 = *very*), how confident did you feel about completing this task and why?

2. Did you try out a strategy when solving the task? If so, what was it?

3. Did you feel more or less anxious and concerned during the more emotional scenario conditions (e.g. school, market place)? Why?

4. Did you find yourself reconsidering your choices at the very last moment, before pressing the mouse button? If so, why?

5. Where you more concerned by the limited time available or the need to be accurate and why?

6. Do you think that you would have been able to solve this task if you had more time available? Why?

7. Did you feel the decision task was solvable? As such, did you find it too easy or too difficult and why?

8. What did you think was the correct solution for the decision?

Appendix E

Experiment 4 (Chapter V) & 5 (Chapter VI)

Post-Task Questionnaire

Participant ID : ______________________ Age: ______________________

Date: ______________________ Gender: ______________________

Please read the questions below and answer them truthfully.

1. On a scale of 1 to 10 (i.e. 1 = not at all, and 10 = very), how confident did you feel about completing the task and why?

2. Did you try out a strategy when solving the task? If so, what was it?

3. Did you feel more or less anxious and concerned during the more emotional scenario conditions (e.g. school, market place)? Why?

4. Did you find yourself reconsidering your choices at the very last moment, before pressing the mouse button? If so, why?

5. Where you more concerned by the limited time available or the need to be accurate, and why?

6. Do you think that you would have been able to solve the task if you had more time available? Why?

7. Did you feel the decision task was solvable? As such, did you find it too easy or too difficult and why?

8. What did you think was the correct solution for the decision?

9. Did you feel pressured to improve your performance, by the instructions give prior and during the experiment?

10. Do you have any further comments to add, regarding the task or the overall experiment?